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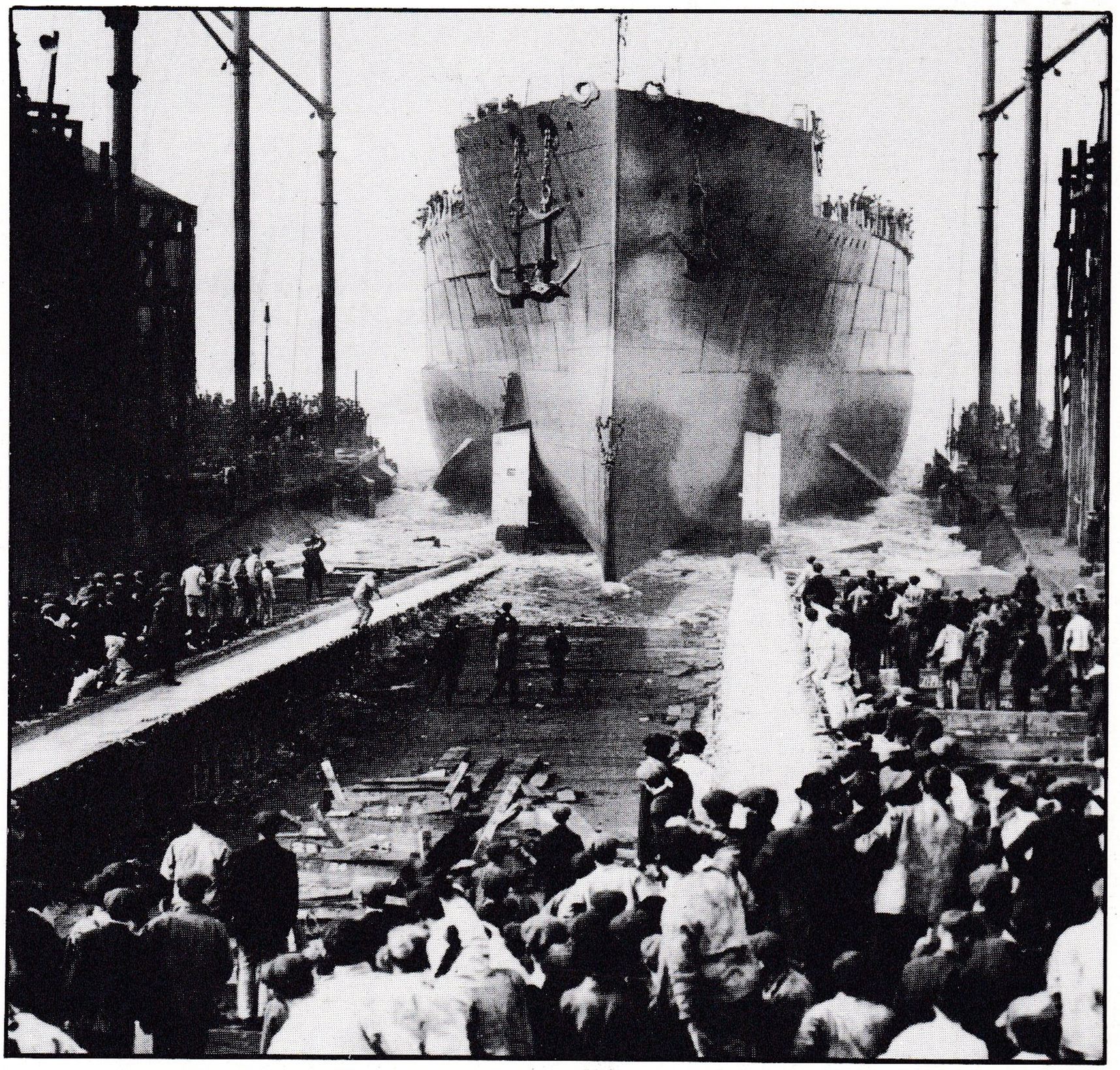

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The launch of HMS Iron Duke, 12 October 1912.
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THE EVOLUTION OF THE DOCKS AND INDUSTRIAL BUILDINGS IN PORTSMOUTH ROYAL DOCKYARD 1698–1914

R. C. Riley, BSc(Econ), PhD

Few would quibble with the proposition that the Royal Dockyard is Portsmouth's *raison d'être* and that since 1496 the fortunes of the two have been intimately intertwined, rendering the town peculiarly susceptible to the vagaries of foreign policy rather than to mere economic metamorphosis. It is this political control of the Dockyard, pouring in money in times of national adversity and sometimes denying the means even to preserve the status quo in peace, that has prompted discrete change where continuous evolution might have been expected had technology and commercial profit been the overriding consideration. The majority of the surviving docks and buildings conform to this model. The earliest date from William III's opposition to France after the Glorious Revolution of 1688, others from the Seven Years' War between 1756 and 1763 or from the Napoleonic Wars ending in 1815. It was the perceived threat of hostilities with France that gave rise to the extensions of the 1860s and early 1870s, and the rearmament race with Germany was arguably the stimulus behind the frenetic expansion at the turn of the century. Only the decision to introduce steam power and new facilities in the 1840s may be seen as primarily technologically induced, although doubtless the minds of the Admiralty were exercised by the strategic dangers of allowing other nations to steal a march.

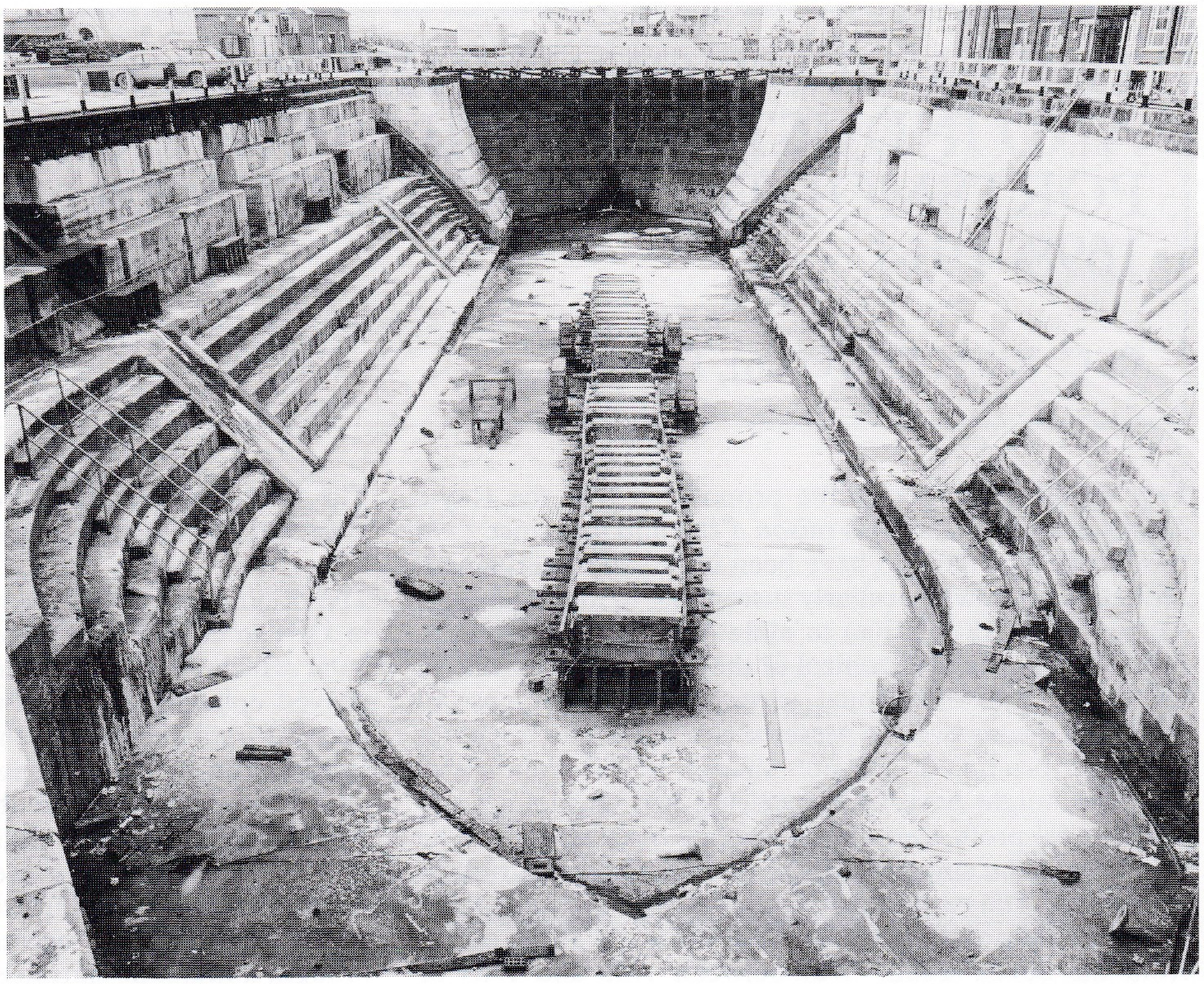
Yet at the same time there can be no gainsaying the role of technology in the development of the Dockyard. Thus an examination of its evolution during the eighteenth and nineteenth centuries affords an insight into the technical and architectural changes in shipbuilding and shiprepairing from the pre-industrial era onwards. During this period stone replaced wood in dock building, iron-framed storehouses ousted earlier wooden structures, metal came to be used for both the framework and the cladding of buildings housing metallurgical operations and for the roofing of building slips, dockside cranes evolved from tiny treadmill-powered edifices to dramatic features in the urban landscape, and the stone trackways of the first railway system gave way to steel rails. While the Royal Dockyards may have been a special case since they were funded from government sources, it is nevertheless arguable that the nature of Portsmouth's technical evolution has application to commercial shipyards and ports in general.

To investigate every artefact that made an appearance in the Dockyard in the period under consideration is outside the scope of this paper. Rather emphasis is placed on those structures that survive and those that have disappeared in the recent past. Inevitably old structures have been subject to modification, but for the sake of cohesion such changes are as far as possible considered together with the first mention of the artefact.

The 1689–1698 Building Programme: Preparation for the War of the Spanish Succession 1702–1713

The origins of Portsmouth lie in the decision by Richard I in 1194 to establish a base on the south coast of England from which he could mount an attack on France. This proved ephemeral and more permanent structures were delayed until the end of the fifteenth century as part of Henry VII's policy of strengthening the Navy. Further expansion was prompted by the First Dutch War of 1652–4, but notwithstanding, Holland's geographical position caused attention to be focused upon the value of the Dockyards at Deptford, Woolwich and Chatham at the expense of Portsmouth. The accession of William III in 1689 brought a dramatic shift in emphasis as France once more became the military target, and in 1689 the government sanctioned a major building programme to be effected at Portsmouth.[1] The nature and scale of the work, completed in 1698, was of national significance in both military and civil engineering terms, and it is fitting that artefacts should have survived. Drawn up by Edward Dummer, Surveyor to the Navy Board, the plan called for the construction of a non-tidal basin, square in plan, from which led a dry dock, and to the north a second, rectangular non-tidal basin separated from the Harbour by a dry dock, the latter being a subsequent addition to the scheme, completed in 1704. Concomitantly, some ten acres of land were to be reclaimed from the sea.

The first mentioned non-tidal basin, which came to be known as the Great Ship Basin, and in the second half of the nineteenth century as No 1 Basin, was built of stone and incorporated at its entrance, double lock gates, the inner pair facing into the Basin and the outer pair towards the Harbour, the better to combat different water levels on each side of the entrance.[2] Otherwise only its size and function were innovatory for its existence allowed a large number of vessels to be fitted out in proximity to essential facilities, whereas previously men of war had to lie in the Harbour in much less convenient positions. Its efficiency was further improved when the sill at the entrance was lowered by 2ft between 1764 and 1765.[3] By comparison the Great Stone Dock, later No 5 Dock, leading from the Basin, represented entirely new thinking. With the contemporary dry dock at Plymouth, it was the first in the country to possess stone stepped sides in place of timbering.[4] There were two steps above the broad altar, or central step, which acted as a walkway and working surface, and seven steps below it, while access to the broad altar from the dock surround was by staircases set amidships, immediately behind the entrance or invert, and at each side of the head of the dock.[5] Although un-



doubtedly costly, there were advantages in strength and watertightness, quite apart from the ease with which a vessel could be shored up with timber baulks and worked upon subsequently. In addition, five slides, two on each side and one at the apex of the dock,[6] were provided to facilitate both the delivery of materials and the removal of planking from the dock, the operation being controlled by gangs of men hauling on ropes. The floor of the dock was made in traditional fashion of wooden planks which were cambered to encourage the flow of water into a drainage channel at the foot of the lowest step,[7] and the planks were carried on a series of piles driven into the mud. The walls of the invert described smooth curves which did not meet, so that the two sides of the entrance were quite separate,[8] a situation which must have been conducive to differential settling and therefore to leakage through the gates. A narrow, straight bridge, possibly resting on the lock gates, appears on a plan of 1723,[9] so it is clear that the notion of using the top of the gates for this purpose had not yet been appreciated. Horse-powered pumps were employed to remove water from the dock.[10] The general principles of the dock layout were similar to those later employed by John Smeaton in his 1793 dock at Ramsgate, presently undergoing restoration.

The experience of the Seven Years' War served to highlight a number of operational deficiencies in the Dockyard, prompting the reorganisation plan of 1761.[11] To increase the mooring capacity in the Great Basin it proved necessary to remove the entrance walls of the Great Stone Dock which protruded into the Basin. This was made possible by the simple expedient of shifting the dock slightly to the east on its original setting in 1769, so that although a new head and entrance were built, the central section of the present dock lies in the exact position of the 1698 structure. The opportunity was taken to reshape the apex of the dock, which had originally had the form of a Gothic arch in plan, with a broad recess flanked by slides, together with longitudinal steps and slides to the broad altar, giving rise to a less graceful, flatter, yet doubtless more efficient shape.[12] It is probable that the dock was also deepened, although the wooden floor was retained. The dock was emptied by gravity discharge to a sump, deepened for the purpose in 1771, built into the rectangular basin to the north.[13] Despite these changes, the overall measurements of the dock remained unaltered.

So far as can be established, the present dock is that which was completed in 1769, with one important modification. The inherent disadvantage of wooden-floored docks was apparent to Samuel Bentham, appointed Inspector General of Naval Works in 1796, and he introduced the principle of a masonry floor, giving the dock the cross sectional form of an inverted elliptical arch, from which it derived great strength.[14] This is especially apparent at the invert since here the masonry blocks are smooth rather than stepped, visually accentuating the arch. Beyond the entrance, which extends some 20ft behind the gates to provide a massive collar into which the gate hinges are pinned, the dock widens into eleven steps, those below the broad altar being less steeply inclined than those above. The topmost step and capstones, or coping, are of granite to combat wear about the rim of the dock, and the masonry is secured by iron bands set in lead. Cut into the riser of the step above the broad altar is a series of recesses which once received timber baulks; their function is unclear, but they may have been used for derricks in the absence of more sophisticated cranage until the twentieth century. The recesses for the gates in their open position are curved, indicative of the design of the original gates.

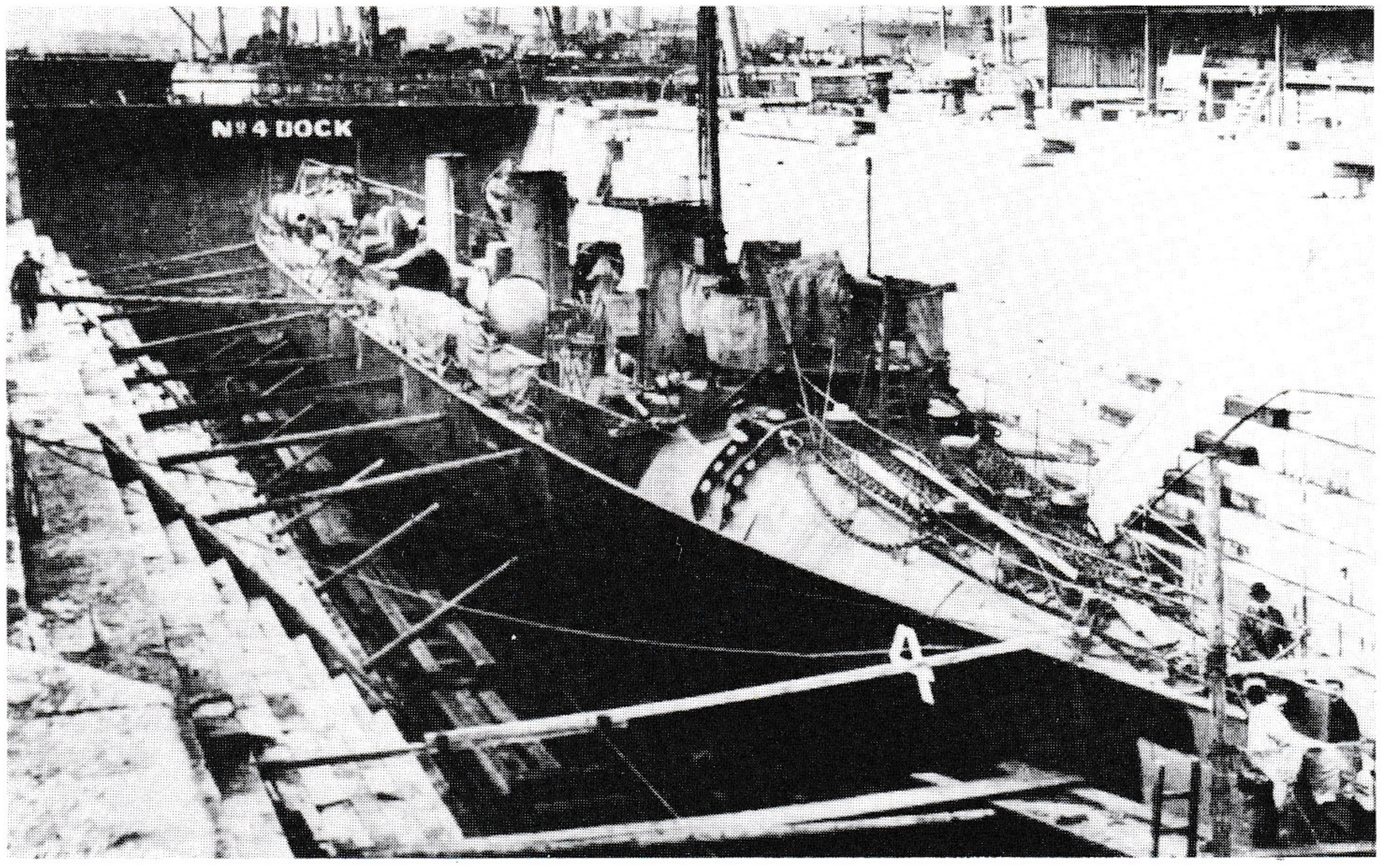
North No 6 Dock, its inverted arch structure and unique drainage channel clearly visible.
Portsmouth Royal Dockyard Historical Society.

The eighteenth century drainage culverts are still in use, and the penstocks are worked by a team of eight men pushing on two wooden bars inserted into an iron spindle. The wooden capstans used to open and close the gates have been removed in favour of metal devices powered by compressed air, manufactured by Cowans Sheldon of Carlisle in 1910. Other changes are surprisingly few: the head of the dock was rebuilt in 1906[15] to accommodate the bows of iron-hulled vessels, with a concomitant increase in length,[16] and the original mooring posts have been replaced by hollow cast iron structures by John Sturgess of the Bowling Ironworks, Bradford. A wooden roof incorporating windows and a novel system of diagonal trussing which avoided the need for space restricting cross beams, designed by Sir Robert Seppings, Surveyor to the Navy Board,[17] was fitted between 1812 and 1814, when the same treatment was accorded to Nos 3 and 4 Docks. Since the roofs protected ships rather than shipwrights, the advent of the iron vessel rendered them superfluous and by 1910 they had been removed.[18]

Remarkably in an enterprise which until the twentieth century experienced substantial if irregular growth, Dummer's rectangular non-tidal basin soon proved to be too large, despite the facilities it afforded for the repair and careening of vessels. By 1725 proposals were being drawn up for the construction of a dry dock within its confines, the remainder of the basin being filled in.[19] Certainly by 1743 it had been reduced in size by one-third and separated from its entrance dock;[20] it became known as the Reservoir since its function was the receipt of water from the Great Stone Dock. In the south-western corner a horse-powered pump, almost certainly of the same design as that installed to pump out North Dock (see below),[21] was constructed to raise water from the sump for discharge into the Reservoir, from which it could be passed into the Harbour at an appropriate state of the tide.[21] Whatever the efficiency of the pump, it was insufficient for the energetic Bentham who, impatient with the slow plod of the animals, in March 1797 installed a 12hp table engine designed by James Sadler, a mechanist on his staff, to take their place.[22] Not only did the Sadler engine predate that of Henry Maudslay, but also it was the first use of steam power in a Royal Dockyard. Within three years it was replaced by a 30hp engine by Boulton and Watt capable of lifting 7 tons of water a minute[23] by means of chain pumps which, although slightly modified, nevertheless endured into the twentieth century. These pumps could also be employed to raise the level of water in the Great Basin should it prove necessary to provide extra depth of water over the dock sills.[24]

Because it was outside the Great Ship Basin, Dummer's small dock, later North Dock and then No 6, between the Reservoir and the Harbour did not become a candidate for relocation, but it underwent extensive modification. It began life as a wooden-sided structure with two outward facing gates.[25] It is not unreasonable to suppose that it was similar in design to other wooden docks of the day. An undated plan of the then existing double dock by Joseph Allin, who worked in the Dockyard in the 1730s, indicates that it possessed sloping wooden walls 20ft in height mounted on wooden piling sunk 12ft into the mud, together with a cambered floor of wood. The invert was, however, of masonry.[26] The shortcomings of the small dock must have outweighed its low construction costs, for by 1737 plans had been drawn up by Allin for a comprehensive rebuild. They show four stone steps above the broad altar and fifteen below, five slides and an 18in declivity from head to stern to encourage drainage;[27] it is likely that the dock was deeper than the Great Stone Dock as first erected. Despite its separation from the basin and reconstruction along the lines of Allin's scheme by 1743, the 1761 plan indicates that further rebuilding was to take place,[28] and it received a new bottom and slides at a cost of nearly £14,000 in 1777.[29] The survival of a detailed drawing provides valuable insight into the method employed to pump the dock free of water. Two gins – large spur wheels 17ft in diameter – were each moved by a team of six horses, and drove cogwheels, on whose shafts, which extended over the sump, were 16 chains of buckets. The whole was enclosed in a building whose ends were semicircular and whose length was almost one half that of the dock it served.[30] Horne remarks that the dock was rebuilt once more in 1810[31] and this could well be the occasion of its receipt of a stone bottom on the Bentham principle. Doubtless because of the proximity of the Reservoir, the head of the dock has not been greatly altered, indeed as late as 1906 the head in plan retained the Gothic arch and drainage channel identical to those of the original Great Stone Dock.[32] Otherwise its slides, vertical recesses above the broad altar and massive invert render it very similar to the Great Stone Dock, but by virtue of its smaller length it bears the closest resemblance to the original form of the early Georgian docks at Portsmouth.

To the south of the Great Ship Basin lay South Dock completed in 1703. Smaller than the Great Stone Dock, it was capable of accommodating only a 60 gun ship as against the latter's 110 gun vessel capacity.[33] Map evidence suggests that it was a wooden structure, despite the assurance of Stephen Leake in 1729 that 'It (the Dockyard) is more compact than any others and the docks are of stone which in others are of wood'.[34] It was also a candidate for rebuilding under the 1761 plan, although drawings seem to indicate that wooden sides were proposed. In the event it was not constructed in this form but was completed in



1801, having been eleven years in charge of the contractor Parlby,[35] as a stone dock a little to the east of the original. Not surprisingly, No 1 Dock, as it now is, was rather longer than the Great Stone Dock, but in essence its scale, gently sloping steps, slides and manually operated penstocks make it a typical eighteenth century structure. Pumping was effected by two horse powered gins on the same basis as North Dock.[36] Even though Bentham was involved in the last stages of its construction, it is unlikely that the inverted arch design was employed. The head of the dock has been adapted to the shape of iron-hulled vessels and its gates are operated by two compressed air capstans manufactured by Cowans Sheldon in 1902 and 1911. However, the presence of mooring posts by John Sturgess & Co adds a mid-nineteenth century touch.

Encompassing the burgeoning industrial complex was a brick boundary wall of English bond construction built between 1704 and 1711, which remains substantially in its original form. Sir Bernard de Gomme had recommended the erection of an earthen rampart protected by a moat, topped by a strong wooden palisade to surround the Dockyard as part of his sophisticated defence system for Portsmouth. This had been completed by 1667, but by the end of the century had fallen into such a state of disrepair that it barely hindered movement. There were many gaps 'through which passed well worn tracks indicative of frequent use for the removal of Government stores'.[37] The replacement wall may be followed along Admiralty Road and Bonfire Corner, where the date 1771 is set into the brickwork, to Marlborough Gate, beyond which it extends within the Dockyard to Victoria Road. A plan of the Georgian docks and buildings appears in Figure 1.

The Stimulus of the Seven Years' War 1756–63

Quite apart from the changes that were effected to structures originating in the reign of William III, the construction of a number of important new buildings followed the approval of the 1761 plan. Further dry dock facilities were regarded as essential and the logic was questioned of having two building slips issuing into the Great Basin, whose function was otherwise concerned with repair and refit work. One of these slips, adjacent to the Great Stone Dock, was certainly in existence by 1723,[38] and the second by 1743.[39] The desirability of locating shipbuilding within specialist work areas, preferably on reclaimed land to the north of North Dock, had been appreciated for at least two decades,[40] and the notion was now translated into practice. No 4 Dock was therefore built on the site of the building slips, its entrance being placed slightly to the east of those of the slips to help increase the area of the Basin. The dock was to be a replica of the rebuilt Great Stone Dock, drainage being achieved by gravity flow through culverts leading to both the Reservoir and the Harbour.[41] It was completed in 1772.[42] Apart from the replacement of the wooden floor by one of stone and brick, uniquely among the Portsmouth docks, and the arrangement of a camber towards the centre line of the dock, itself unusual, No 4 Dock experienced scant change until 1858 when it was selected for lengthening.[43] Completed in the following year, [44] the dock reflected developments in civil engineering and the need for a wide entrance to accommodate the wheels of paddle steamers. The walls of the entrance did not abut into the dock forming a narrow and space-wasting collar as formerly had been the case, rather they followed the outline of the coping of the dock. The entrance walls described a steep linear slope which was later – probably subsequent to the Great War – matched in the body of the dock by the effective removal of the steps above the broad altar by concreting and the use of space so generated for crane tracks. The six slides were thus truncated at the broad altar. The 1858–9 rebuild incorporated a caisson or pontoon located to the west of the former conventional mitre gates. The head of the dock was moved outwards and given a square profile, but unusually was provided with a notable recess cut vertically at mid-point to take ships' bows in an effort to extract every inch of space from the structure. No 4 is the deepest of the old docks, a phenomenon which causes it to be the first to flood if for any reason the water should back up in the Reservoir.

A destroyer in No 4 Dock, c. 1910.
Portsmouth Central Library.

The corollary of the demolition of the building slips leading into the Great Basin was the construction of such facilities on reclaimed ground elsewhere. Messrs Templar and Collard were contracted in 1764 to build two new slips,[45] which were given simple wooden roofs without head or sides in 1776.[46] Piling for further extension work was begun on 27 April 1780,[47] and by 1784 three slips were in existence with a fourth, described as 'Tophouse', proposed for completion in 1786,[48] although it had not been built by 1810.[49] This reflected the Navy Board's policy of relying on private yards for much of their building work, and the use of Royal Dockyards for fitting out, repairs and refits.

The construction and maintenance of ships had important logistic implications. While the somewhat rudimentary wooden-faced[50] Camber Quay in the south-west of the Dockyard might have sufficed in the early eighteenth century for the reception of materials from merchant vessels which were required to rest on the mud at low tide, it was manifestly unsatisfactory for the greater influx of goods occasioned by the Seven Years' War. Even so the necessary modernisation work was not placed with the contractors, Templar and Parlby, until 3 September 1773.[51] The result was a robust Portland stone, rectangular tidal inlet known as the Camber, some 660ft in length, completed in 1785, located to the south-west of the former quay, thereby creating considerable quayage space for the assembly of delivered stores. The vertical movement of ships with the tide must have presented problems for unloading and partly to overcome this between 1801 and 1807 a caisson or pontoon was inserted at the south-eastern end of the Camber,[52] rendering the 220ft section beyond non-tidal. A culvert was introduced to the Harbour allowing the water level on each side of the caisson to be equalised; water pressure would, for much of the time, have otherwise immobilised the caisson. When stores came to be delivered by rail and merchant ships increased in size, the Camber lost much of its usefulness and the caisson was replaced by a fixed bridge on piling, which is still in place. The problem of the transfer of goods from ship to shore was overcome by the use of three wooden treadmill cranes, each with twin drums within which a man was required to exert downward pressure, thus generating rotary movement. That the weight of two men proved effective in lifting many times this mass was a result of the 7ft 6in radius of the drums and the use of a pulley block attached to the hook.[53] Doubtless traversing was effected by ropes attached to the jib which extended some 16ft from the pivot. It is likely that these devices would have been able to raise loads of up to about half a ton in weight. A double treadmill crane, together with four hand cranes operated by a wheel at one end of the main shaft, were at work on the old Camber Quay as early as 1698,[54] and it is conceivable that the manual type had been converted to treadmill operation by 1774. However, Horne notes that those in position in 1760 possessed a single drum.[56] The inherent instability of such an arrangement would suggest that the single drum was probably a hand wheel, and that in all probability the general introduction of treadmill cranes did not occur until the 1770s. Construction work south of the Camber included the provision in 1797 of a pair of lock gates in the short entrance passage and tunnel from the Harbour to the Mast Pond,[57] since it was necessary for spars to be constantly submerged in their stocks, calling for the maintenance of the water level. These gates faced opposite directions to combat unequal height of water, but once the Mast Pond lost its function with the advent of metal ships and came to be used as a Boat Pond, a third pair of lock gates was inserted allowing boats to be locked in and out at any state of the tide.[58] The tunnel and gates, permanently open, may still be seen.

Consequential upon the arrival of stores in the Camber, it was logical that storehouses should be established nearby. The appreciation of the fire risk inherent in wooden structures caused the 1761 plan to call for the use of brick buildings, many of which were clustered round the Camber. Collectively they constitute fine examples of Georgian industrial architecture, which justifiably have been accorded attention by many writers.[59] They are characterised by red brickwork laid in English bond, parapets partly masking the dormer windows set in the side of a shallow pitched roof, regular fenestration, Portland stone string courses, and an appearance of powerful simplicity. Their wooden flooring is supported on substantial wooden columns, and the inside walls are faced with timber. The storehouses are uniformly slim in plan, being approximately four times as long as they are wide, indicative of the way access is facilitated by such an arrangement; vertical movement seems not to have posed problems.

Three storehouses, arguably the most distinctive in the Dockyard, were built on the north-east side of the Camber, all being the work of Templar, Parlby and Templar.[60] Present Use Store, now No 11 Store, was completed in 1763, prior to the commencement of work on the Camber, and served as a prototype for the others: Middle Store or No 10 erected in 1776, and South Store or No 9 opened in 1782. Each has three floors, an attic and a cellar, a central pediment edged in Portland stone and a series of stone-framed doors. The present doors are not original, but the presence of iron brackets on the transoms, and brass plates in the threshold stones, indicates that the first doors swung outwards. They were locked by means of a bar fixing into brass slots marked with small arrowheads set in the architrave. Above the transoms are typical Georgian glazed fan-

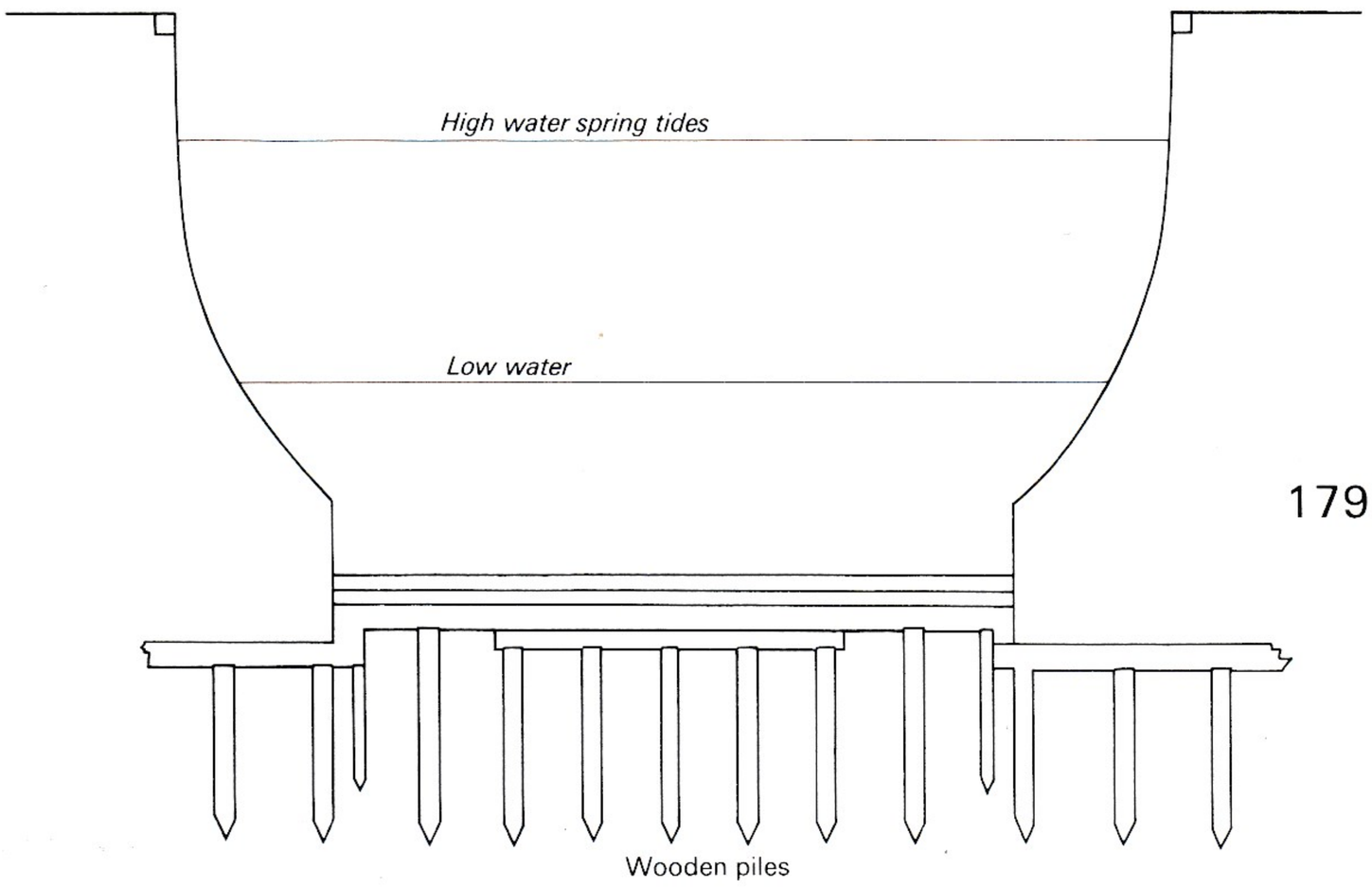
1 Steam Basin
2 S.B. original entrance
3 Steam Factory
4 Smithery
5 Engine Houses
6 No.3/4 Slips (covered)
7 No.5 Slip
8 No.2 Slip
9 No.10 Dock
10 No.7 Dock
11 No.8 Dock
12 No.11 Dock
13 Armour Plate Workshop
14 Block Mills
15 Clothing Store/Smithery
16 Steel Foundry
17 Brass Foundry
18 Iron Foundry
19 N.W. Building
20 No.1 Dock
21 No.2 Dock
22 No.3 Dock
23 No.4 Dock
24 No.5 Dock
25 No.6 Dock
26 Great Ship Basin
27 Mould Loft
28 S.W. Building
29 S.E. Building
30 Water Tank
31 Hatchelling House
32 Railway Waiting Room
33 Royal Shelter
34 No.1 Store
35 Chain Test House
36 No.3 Store
37 No.9 Store
38 No.10 Store
39 No.11 Store
40 No.12 Store
41 Boat House
42 Boiler Shop West
43 Great Ropery
44 No.15 Store
45 No.16 Store
46 No.17 Store
47 No.7 Boathouse
48 No.6 Boathouse
49 No.5 Boathouse
50 Pay Office
51 Dockyard Wall
52 Main Gate

N

0 100metres
0 300feet

Fig 1 The Georgian and Early Victorian Docks and Buildings in Portsmouth Dockyard.

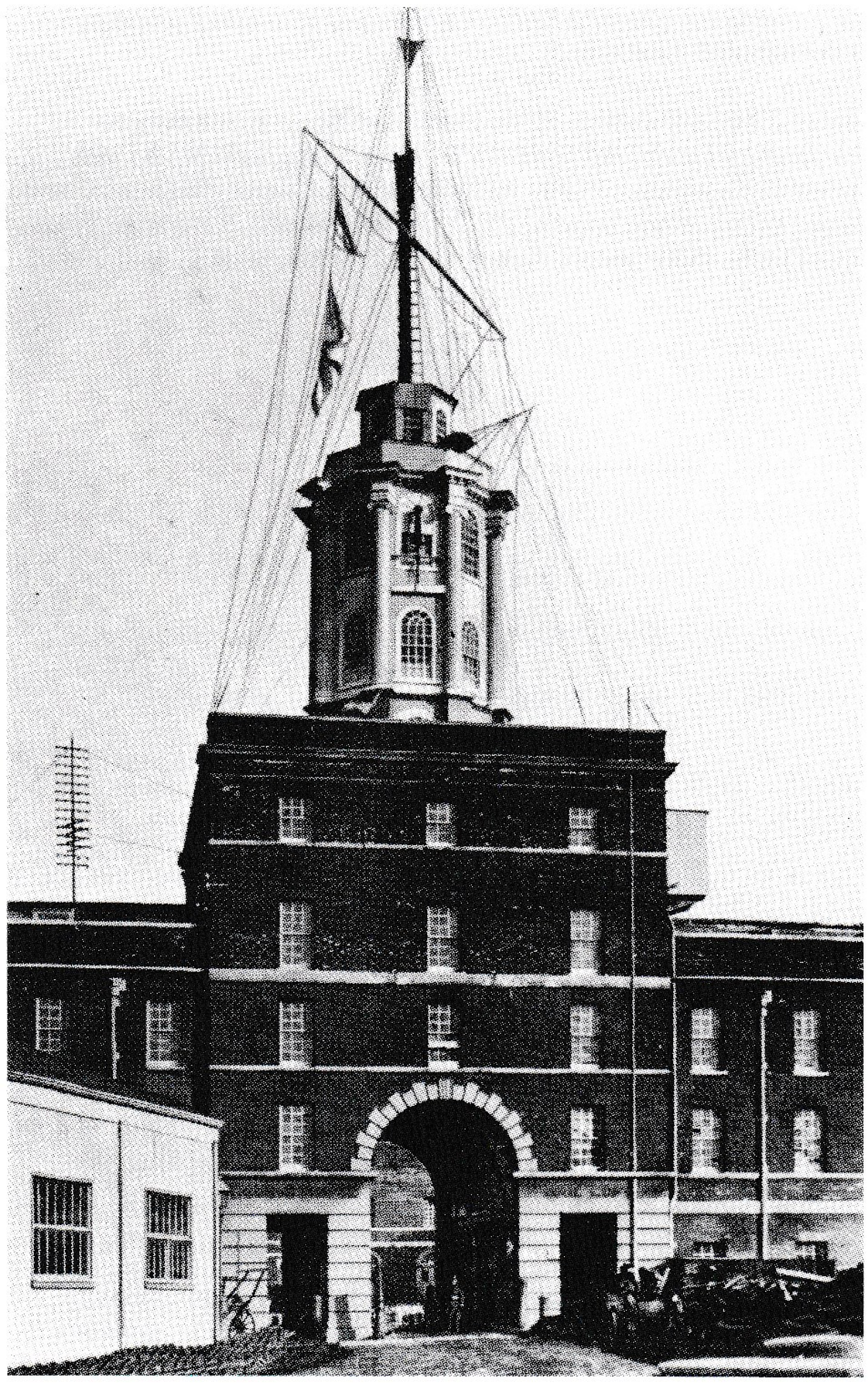
Figure 2 The Evolution of the Dock and Basin Entrances at Portsmouth Dockyard 1797–1850. Upper diagram: No 3 Dock, drawn 1797; source, PRO, ADM/140/573. Centre diagram: Great Basin, drawn 1799; source, PRO, ADM/140/581. Lower diagram: No 8 Dock, 1850; source James, *op. cit.*, Plate VIII.i.



lights. Access to the cellars was by steps on the Camber side, but with the exception of two sets at Present Use Store, the steps have been blocked off and iron grilles inserted; since those at Middle Store bear the name 'W.H. Sperring Landport', they must postdate the 1860s. Diminutive wooden cranes nestle in the frame of the central second floor windows facing the Camber, but on the evidence of the large round-headed doors in the gable ends at first floor level, it seems clear that most vertical lifting was executed at these points. This is supported by the later addition of metal wall cranes whose jibs carried over to the railway track laid at the rear of the storehouses. Mounted above the Middle Store was an elegant cupola and clock, redolent of that which survives at Chatham, from which the Dockyard took its time. Sadly it fell victim to an air raid in 1941. The interior of Present Use Store was gutted by fire in 1874, but was rebuilt as the original in 1879,[61] thankfully preserving the impressive vista along Main Road.

Facing these three storehouses across the Camber were built the Sail Loft and the Rigging Store, completed in 1784 by the same contractors using similar designs.[62] The Sail Loft had the same length and breadth as the earlier storehouses, but the Rigging Store was some 330ft long, making it the longest store in the Dockyard by some margin. At some time between 1810 and 1824[63] Semaphore Tower was constructed in the space between the Sail Loft and the Rigging Store in matching architectural style, a large archway being provided at ground floor level in order not to impede traffic using the Camber caisson. Unfortunately these fine buildings were destroyed by fire on 20 September 1913, but the Semaphore Tower and Sail Loft, designed for office use, were imaginatively rebuilt in Georgian style in 1929. By a stroke of quite remarkable inspiration, Lion Gate, a powerful architectural feature which had formerly graced the eastern end of Queen Street from 1777, was resuscitated to form the arch below the Tower.

More muted than the storehouses at the Camber were those built to the east of Middle Store parallel with the Great Ropehouse. Very much in the Georgian mould, and only slightly marred by the subsequent addition of buttresses, were West and East Sea Stores, completed in 1771, and two specialist stores, the West and East Hemp Stores, both of which had their respective dates of construction, 1771 and 1782, worked into their eastern gable ends. By the 1870s, when hemp was no longer needed, West Hemp Store had become the Gunboat Engine Store and East Hemp Store the Furniture Store.[64] West Sea Store was destroyed in 1941. Noticeably the excrescences of nineteenth century cranage are missing from these stores, which preserve an air of quiet dignity not unassisted by the proximate ambience of St. Ann's Church completed in



1787. It was not always thus for the space between the storehouses and the Ropehouse was used as the Anchor Rack from 1774[65] until the Great War.

Four buildings constructed between 1786 and 1790[66] furnish a commentary on the craft-based trades that predominated at that time, for in the absence of heavy and immobile equipment in almost all the production processes, it was perfectly feasible to design workshops and storehouses under the same roof. Ranged round the Parade Ground to the east of the Great Basin, they were almost square in plan, but effectively comprised two slim buildings separated by a courtyard, access to which was through arched doors at each end.[67] Above the entrance arches offices were positioned.[68] The South-East Building, now No 25 Store, is architecturally the most attractive. There are two floors, and the north and south elevations feature pediments fringed in Portland stone, enclosing circular and elliptical apertures of rubbed brick. Entrance to what are now entirely storehouses is through tall rectangular doors with wooden moulded frames. Adjacent is the South-East Building, now No 24 Store, which is superficially very different following the addition of a storey and the removal of the distinctive skyline embellishments of its neighbour. The ground floor has the same striking doorways, and contractors working in the courtyard in 1984 unearthed a layer of cobblestones as a reminder of the

The original Semaphore Tower, c. 1910. The Rigging House is on the left and the Sail Loft on the right.
Portsmouth Central Library.

highly uneven surfaces of yesteryear. The upper floor once served as a mould loft, where full-sized templates of vessels were laid out.[69] The North-West Building, now the Yard Services Manager's Offices, has undoubtedly lost some of its architectural merit through the addition of a further floor, but it is clear that it never possessed the panache of its fellows to the south and its functional appearance is relieved only by round-headed doorways in the north elevation. The North-East Building was destroyed in the Second World War.

Since so much wooden shipbuilding, repair and fitting out took place on the slips, in the docks and the Great Basin and at sea, and because associated manufacturing processes were small in number, it is not surprising that the Georgian legacy of production shops is attenuated. Nevertheless the decision enshrined in the 1761 plan to make the greatest possible use of brick to inhibit fire has engendered the survival of a number of important buildings. A fortuituous glimpse of the nature of timber buildings can be obtained from the anachronistic Nos 5 and 7 Boathouses, which despite their construction in 1882 and 1875 respectively, are single storey, timber-framed and wooden-clad with proud window frames containing tiny panes. That they stand on metal piles driven into the Boat Pond may explain the need for light structures, but their fenestration is entirely Georgian.

The evolution of naval vessels since the eighteenth century has meant that the early manufacturing premises have lost their function and are used as stores, which explains their survival. The largest is the Great Ropehouse, completed in 1770 and restored after a fire, its brick construction notwithstanding, in 1776. Its great length of 1,095ft renders it perhaps the most distinctive feature of contemporary plans, and so effectively did it split the Dockyard that when ropemaking was concentrated at Chatham and the Ropehouse closed in May 1868,[70] the opportunity was taken to drive an archway through it. Yarn was spun in the upper of its three floors, hence the term 'double ropehouse', signifying its dual function – hitherto spinning was undertaken in separate premises – and rope was wound below. A 1775 description remarked that 'some of the cables are so large that 80 men are required to work them, who, from the laboriousness of the work are not able to continue at it above four hours in the day'.[71] Even in an age of outstandingly cheap labour this arrangement came to be regarded as inefficient, and a 6hp steam engine 'of a peculiar construction'[72] was installed to assist the process, probably in the early nineteenth century. The floors of the building were paved with cast iron and tin in an attempt to prevent a repetition of the previous disaster.[73] This huge factory remains largely unchanged, although the attic windows were removed in the 1940s and some of the flooring is now carried on steel piers. At the eastern end of the Ropehouse, the Hatchelling House, where fibres were carded in preparation for spinning, was constructed in 1771. During the Napoleonic wars the two premises were linked by a passageway to secure the movement of prisoners employed at the time, and the walkway set in the roof trusses of the Hatchelling House for the convenience of the overseer, may date from this period. One of the supporting arches of the passageway was bricked up in 1815 and used until 1846 as the fixing point for a timber, rope and chain testing mechanism located at a distance of 200 yards, or one cable length, but nothing of this survives. The device was the work of Simon Goodrich, Engineer and Mechanist in the Dockyard from 1814 to 1830, and the stress was applied by a hydraulic ram operated by rocker arms worked by six men.[74] Completing this manufacturing complex was the Hemp Tarring House, opened in 1770, near the western end of the Ropehouse; it is now Boiler Shop West and is much altered.

An indication of the relative importance of the functions of the industrial buildings considered may be deduced from a listing of Dockyard occupations on 14 January 1774. There were 861 shipwrights, 134 sawyers, 115 spinners, 85 smiths, 82 house carpenters, 82 caulkers whose basic material was tar, 75 scavelmen who were responsible for the operation of the docks, 67 riggers, 64 joiners, 55 bricklayers, 51 sailmakers, 20 riggers' labourers, and 18 hatchellers. Doubtless the importance of house carpenters, joiners and bricklayers was a result of the scale of the building programme at the time, but the absence of ropemakers is puzzling. The total workforce was 2,198, which if the 685 men working on the ships in ordinary, that is, the reserve fleet anchored in the Harbour, are included, rises to 2,883,[75] constituting an enterprise of enormous proportions by the standards of the day. The Napoleonic wars were to see the Dockyard assume even greater significance, for by 1814 no less than 3,900 were employed, a figure exceeding that of Chatham, its principal rival.[76]

The Napoleonic Wars 1793–1815

No sooner had the War of American Independence ended in 1783 than six years later the French Revolution began, and by 1793 England was once more at war. The inevitable result was an enquiry into the capacity of the Dockyard, and Samuel Bentham was invited to prepare a report and to make recommendations, which he submitted on 29 May 1795. He noted that the practice of undertaking repairs in the Harbour was the source of much abuse since dockyardmen spent an excessive amount of time rowing to and fro, termed 'afloat time', that much material disappeared, and that inadequate supervision gave rise to poor quality work.

The interior of Middle Building, Wood Mills, illustrating some of Brunel's pulley block making machinery.
Portsmouth Central Library.

As a consequence he proposed an extension of the Great Basin to allow twelve ships of the line to be berthed for repairs afloat. He also pointed to the shortcomings of double docks, which effectively caused the inner vessel to be trapped by the outer, and argued that the Great Basin could be extended over the double dock while at the same time two conventional docks could be introduced leading from the enlarged basin.[77] In the following year he was invited to put his proposals into practice.

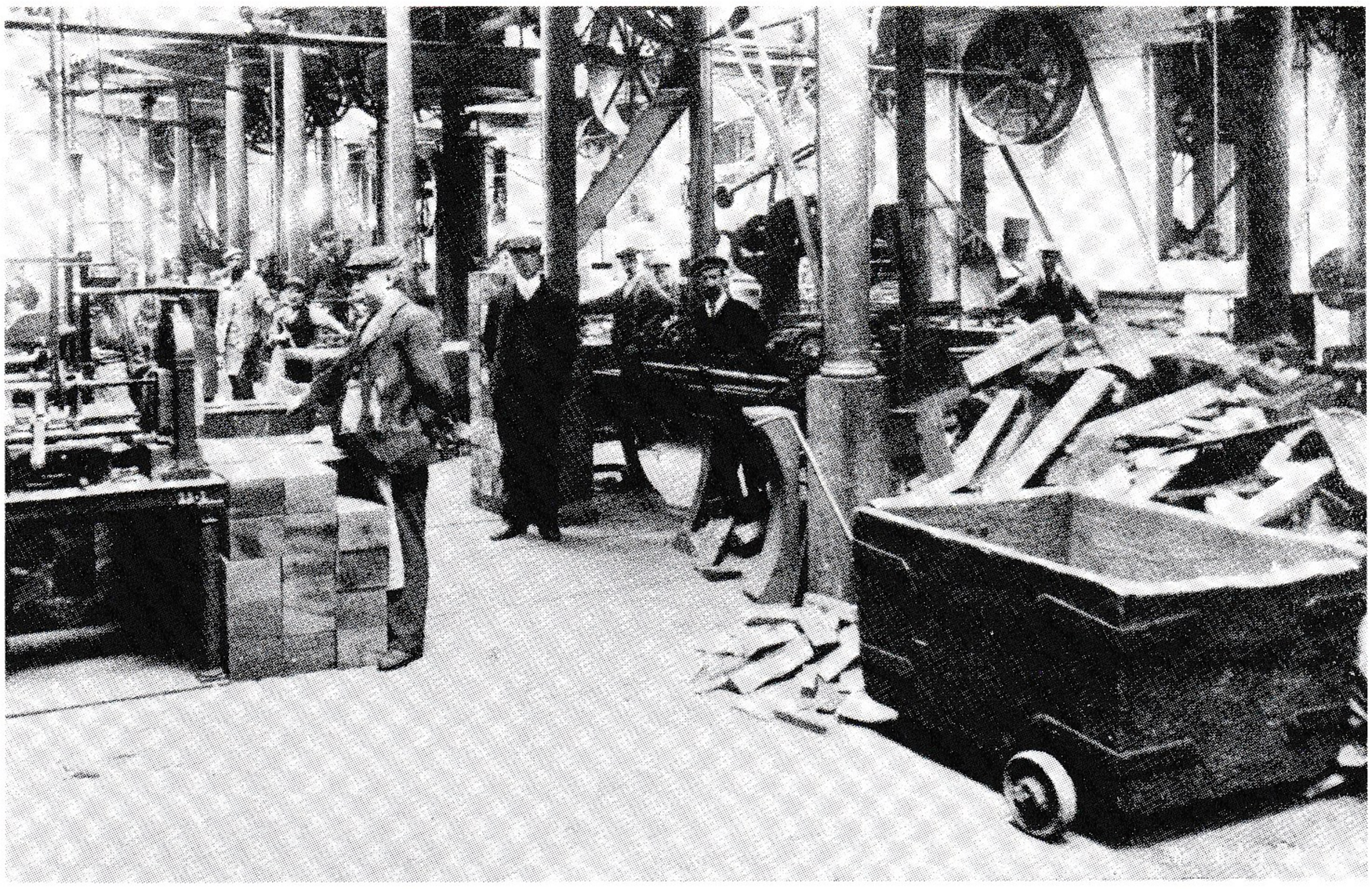
Within months of taking office Bentham had finalised his plans[78] and the work of doubling the size of the Great Basin proceeded, timbers and tree trunks secured by trenails,[79] almost certainly the relics of the first dock of 1496, being uncovered in the process.[80] In one important aspect the initial proposals were not adhered to. At the outset the entrance to the Basin was to have been a replica of Dummer's earlier structure, incorporating two sets of gates, one opening inwards and the other outwards in the direction of the Harbour,[81] the entrance sill being constructed of timber in the conventional fashion.[82] By 1798, however, Bentham had conceived the notion of tying both entrance walls together with masonry in the form of an inverted arch,[83] fixed in position by cement patented by Smeaton. The advantage of this structure was a reduction in settling and a concomitant diminution of leakages; moreover a masonry sill was more durable than one of timber. It is thought that this was the first use of the inverted arch principle in dock building. A cross section of the entrance and of that proposed is shown in Figure 2.

It would be erroneous, however, to view the new entrance in isolation, for its very nature proved conducive to the introduction by Bentham of a further innovation, the caisson in place of mitre gates.[84] The caisson, or floating dam as it was originally known, was a boat-shaped wooden structure which could be sunk in position across the entrance by flooding with sea water, which could be pumped out causing the caisson to float when access was required. Possessing a keel extending fore and aft meshing with an appropriate recess in the masonry, the caisson was elliptical in plan, although it was given a decking in order that it could be used as a roadway. Its end elevation was akin to that of modern destroyers,[85] but this proved somewhat unstable and later caissons paradoxically followed the lines of the traditional men of war, bulging outwards to the waterline. Since the caisson was designed to hold 171 tons of water,[86] it is not surprising that it was fitted with four manual pumps which were a feature of Bentham's patent,[87] although the process of evacuation in all probability endured longer than flooding which was achieved by the ingress of water through an 11in diameter pipe.[88] The caisson was built by the Master Shipwright in the Dockyard.[89] Apart from the absence of potentially troublesome hinges, its watertight quality and its transport function, the caisson required only 40 men to operate it, compared with the 90 required for the South Dock.[90] While it is perfectly possible that the use of an inverted arch was simultaneous with or even consequential upon his decision to install a caisson, there can be little doubt that in their combined use Bentham had made a major contribution to dock engineering. Replacement timbers were being sought in 1849,[91] but since iron caissons were then in service, it is possible that such a structure was introduced.

The enlarged Basin was completed by the contractors, Thomas and John Parlby, on 12 June 1801, when HMS *Britannia* sailed through the entrance, an event commemorated by an inscription on both walls. Reflecting Bentham's policy of using the Basin for refit and repair work was the erection in 1835 of a pair of 142ft long sheer legs to the north of the entrance; a second pair was added over the Harbour in 1837.[92] With a lifting capacity of 25 tons, these sheers represented a substantial advance in fitting out and repair technology; they were later operated by steam winches fed by pipe from the boiler house in the Wood Mills.[92]

The first of Bentham's dry docks, No 2, which has held HMS *Victory* since 1922, was begun in 1799 and was completed in 1802, the contractors being Parlby and Rankin.[94] Its dimensions almost exactly replicated those of the slightly earlier South Dock, but its head was rather more sharply fashioned than the semi-circular design of South Dock. The narrow stairs which flanked the sides of the head in the latter dock were dispensed with, Bentham preferring two sets of wide stairs giving access to the broad altar through a short tunnel with a right angle turn, thus avoiding undue interference with movement around the edge of the dock. It has not yet been established whether Bentham accorded the dock an inverted arch, nor is it certain when its stone bottom was built, although it predated 1862. This is of particular importance for the bottom of the dock is its most novel feature. The lower steps at the head and stern are built out into the dock so that the three lowest are wider than the broad altar, constraining the floor at the head to a width of 9ft, and to a mere 7ft at the stern; even the main floor of the dock is only 24ft wide.[95] The rationale was doubtless to improve access to the underside of vessels. Between 1803 and 1806 a culvert was dug from the head of the dock to the Mast Pond,[96] probably to facilitate the raising of the water level therein rather than as a method of draining the dock, which was achieved by culverts set in the invert in the normal fashion.[97] Of all the Georgian docks, this is the least altered, and in the light of its charge, wholly appropriate.

The second of Bentham's docks, No. 3, which was finished in 1803, now host to the *Mary Rose*, was originally



designed with a wooden bottom,[98] but Coad is of the opinion that the dock may well have been the first to receive an entrance and stone floor on the inverted arch principle.[99] The argument is certainly defensible for the advantages of such a structure are clear, and having successfully built the Basin entrance in this way, it is logical that it should also be applied to docks. Perhaps the construction of the earlier No 2 Dock was too far advanced when the decision was made to apply the new method? In any event there was considerable similarity between the floors of both docks; the lower three steps at the after end of No 3 curved into the centre of the floor so they almost met, leaving a gap of only 4ft. On the other hand, far from curving beneath ships' bows, the steps at the head were truncated to give a width greater than that in the body of the dock,[100] creating a floor profile unique among the Portsmouth docks. Additional length was engineered in 1859 by the insertion of a caisson beyond the former gate recesses, together with an invert of steeply sloping granite blocks.[101] The inward curving steps were simultaneously removed. Drainage was achieved by gravity flow to the Reservoir through brick lined culverts which are still in use, although they were supplemented by larger elliptical culverts placed 10ft below them in 1848 when the Great Basin drainage system was linked with that of the Steam Basin.

Noting that the water level in the 30ft deep Reservoir never exceeded 6ft,[102] Bentham determined to put this space, which was otherwise wasted, to good use, and in 1799 he constructed a double tier of brick vaulting over the water. The floor immediately above the Reservoir was used for the storage of pitch, tar, turpentine, tallow and oil,[103] and to avoid the possibility of damp air fouling these stores Bentham arranged for the passage of air by using the steam engine installed above to engender a draught. Horne notes that when the engine was dismantled this function was overlooked and damp soon rendered the floor useless for storage purposes, although it was used as an air raid shelter in the Second World War.[104] At ground level the Wood Mills were built, and to the east the Plumbers' Shop was later constructed. Bentham had himself taken out patents on circular saws and determined to rationalise the basic woodworking processes in the Dockyard. More importantly he was immediately impressed by the potential savings inherent in the designs for the manufacture of pulley blocks submitted to him by the gifted Marc Brunel, and he obtained permission for the production, between 1802 and 1806, of 45 machines, many of which were highly sophisticated, by one of the country's leading engineers, Henry Maudslay. Together the machines constituted the world's first example of the use of metal machines for mass, but not flow, production,[105] enabling a mere ten men to undertake the work of 110 craftsmen in the manufacture of 140,000 pulley blocks per annum. There is substantial literature on the subject of the machinery,[106] but since the Wood Mills were the first steam-powered factory in a Royal Dockyard, a general description is appropriate. They comprised two timber-framed parallel buildings of three floors, known as North and South Buildings, separated by a single storey Middle Building whose interior wooden columns were circular in the classical Tuscan style. The ground floor of the North Building housed a series of large saws, the first floor was used for the manufacture of pulley block wheels, or sheaves, and the upper floor doubled as a store and small workshop. Pulley block shells were produced in Middle Building. The steam engines that powered the machines and the chain pumps of the Reservoir sump occupied the ground floor of the South Building; the upper two storeys were stores and small workshops, above which was a water tank for fire prevention purposes, an indication of Bentham's appreciation of the great potential hazard from this direction.

The notion of mass production executed by a large number of machines implies that there is a process sequence and therefore an optimum location of machines to minimise the movement of materials. Considering the historical significance of the pulley block assembly process, it is somewhat surprising that scant attention has been paid to the way in which Bentham and Brunel resolved the problem. An important exception is the work of Cooper who

has been able to suggest a sequence for the production of shells in Middle Building by interpreting a line shafting diagram.[107] There were three sets of machines each making pulley blocks shells of different sizes, arranged in a hollow rectangular round the building. The production sequence of boring, mortising, cornering, shaping and scoring was identical for each of the three assemblies. The line for small shells ran from north to south at the east end of the building, and the medium sized shells were made from east to west along the south wall. Following their size, and concomitantly that of the machines, coupled with the need for additional stacking space, the large shells were assembled from south to north at the western end of the shop, continuing round along the north side from west to east. In other words, both within each assembly line and in respect of the three lines together, there was a clockwise progression round the premises, undoubtedly reducing effort.

A drawing of the machinery layout in the late 1950s,[108] later carefully annotated by Maurice Gould, confirms the general principles of Cooper's findings, although inevitably some reorganisation had been effected in the intervening century and a half. The drawing also sheds light on some of the *non sequiturs* noted by Cooper. Firstly, the absence of a scoring machine in the small shell assembly line is explained by its location in a small extension, which existed in 1810,[109] to the east of the building. The extension, which is not mentioned by Cooper, had its own line shafting, driving machinery which would not therefore be mentioned on the line shafting diagram for the main building. The drawing indicates that by the 1950s, the smooth flow of materials between the small shell assembly line machines has been somewhat reduced; boring was carried out in the extension, mortising, cornering and shaping in the main building, but the shells were taken back to the extension for scoring. The presence of a second, small shaping engine in the extension might have removed a production imbalance, but it did not reduce the flow of materials between the extension and the main shop. That there were two further small scoring machines at the western, opposite, end of the building is curious, although these were almost certainly not Brunel machines.[110] Secondly Cooper notes the inappropriate location of the converting engine for the production of the initial blocks of wood amid the small shell machines, and argues that it would have been better positioned to the north-west. The Gould plan shows three circular saws with an attendant overhead hand winch in precisely this siting, suggesting that the error was recognised, although when is impossible to say. In this position the circular saws were centrally placed to serve the five boring engines in the shop,[111] although as Cooper remarks, considerable cross hauling would have ensued.

In the absence of early drawings of the first floor of the North Building, where sheaves and pins to secure the central bush to the sheave were produced, it is conjectural to project the machine layout of the 1950s to the Brunel period. However, Gould's diagram unquestionably depicts an ordered sequence of sheave making machines which were placed along the north wall of the building. In order from east to west, there was a horizontal saw, a rounding saw, a second horizontal saw which is still in position, two coaking engines to cut recesses for the brass coak or bush,[112] a drilling machine to fashion rivet holes for the coak, a broaching engine to smooth the face of the coak, and finally, three lathes to groove the edge of the sheave and to give an even surface to the sheave as a whole. This progression, together with the number of machines involved at each stage, is very close to Brunel's original listing reproduced by Gilbert,[113] and it seems clear that here, no less than in the Middle Building, Bentham and Brunel were able to demonstrate their pioneering flair in both production and mechanical engineering.

Pulley block production ceased in the 1960s, but a small number of Brunel's machines remain in the North Building. The most impressive is his swing arm horizontal circular saw for cutting *lignum vitae* for the sheaves, and at a smaller scale yet equally ingenious are a scoring machine, a lathe for the manufacture of trenails, and a corner saw. Two of Brunel's outstanding designs are exhibited at Southsea Castle Museum: his mortising engine that operated at 400 strokes a minute and which is reputed to have been the largest metal machine tool in the world at the time of its manufacture, and a shaping engine in which ten shells revolved on spindles and were simultaneously rotated and cut by a gouge. On the ground floor of the North Building, dating from the 1880s, is a large wood planer by Samuel Worssam of the Oakley Works, Chelsea, and in Middle Building layshafts, belt wheels and manual, fixed hoists testify to the former presence of this innovatory system of manufacture.

Contrasted with such *éclat*, other developments were muted. A Smithery was built at the northern end of the Dockyard, but the premises lost this function with the opening of a new Smithery in 1852, and they became a clothing store, and later, the North Office Block. The date of construction is unclear, for although the plaque proclaiming its ancient monument status cites a date of 1791, a Prussia Deal House stood on the site in 1810,[114] although it is likely to have been built shortly afterwards. Bentham's concern with fire hazard was seen in his construction of a water tower and a ring main serving major buildings, completed in 1808 according to one authority,[115] although its absence from a map of 1810 indicates a later date.[116] The

original was replaced *c.*1843 by an iron structure of two tiers of arched girders above circular columns, tied with bracing, which Pevsner and Lloyd regard as 'a landmark in constructional history'.[117] The 770 tons capacity metal water tank, which also supplied cooling water for steam engines' condensers,[118] has been removed. The framework, clad with corrugated iron, was for many years the Dockyard fire station.

The Advent of Steam Power in Warships.

For almost three decades after the conclusion of the Napoleonic wars the Dockyard experienced a period of retrenchment. This was brought to an end by improvements in steam engine efficiency[119] and the development of the screw propeller by Francis Petit Smith in 1836, rendering sailing ships obsolescent. While steam power could be translated into movement only through paddle wheels, it was hardly a proposition for fighting ships, for paddles were vulnerable to attack and their wheels seriously reduced the number of gun ports in their hulls. Once the propeller-driven HMS *Rattler*[120] had proved its superiority over the paddler HMS *Alecto* in 1840, the way was open for the introduction of steam technology. The outcome was a programme of work initiated in 1843, its execution and supervision being undertaken by a group of Royal Engineers officers, foremost of whom were Captain Sir William Denison, Captain H. James, Captain R. I. Beatson and Lieutenant Colonel Brandreth.

Central to the extension work, both operationally and geographically, was the 7 acre Steam Basin, on which work began on 29 May 1843 and which was opened on 25 May 1848, four days before schedule.[121] The contractors were Peter Rolt and Benjamin Bramble, a Portsmouth Borough Councillor, and costs were contained by the use of 1,200 convicts from hulks moored in the Harbour,[122] although 1,050 wage labourers were also employed.[123] The floor was laid on a timber grillage, the walls were faced with granite backed by masonry rubble and concrete,[124] and the entrance was closed by a metal caisson made by the firm of Fairbairn at a cost of £5,260.[125] The entrance was subsequently found to be inadequate and another was constructed to the east between 1870 and 1873,[126] coming into service in 1876. The original caisson was left in place and walled in, to be revealed during road surface repairs in 1984. It proved to be boat-shaped with bows at each end above which was a cantilevered decking as in Bentham's prototype, permitting its use as a road and railway. High quality wrought iron was employed together with shipbuilding techniques similar to those of Isambard Brunel's *Great Britain*.[127] Despite technical advances in other fields, hand cranes were still considered effective, although the use of gearing allowed them to raise substantial weights. Thus two manually operated cranes, one of $7\frac{1}{2}$ tons and another of 15 tons capacity with a fixed jib, were positioned at the western end of the Basin. Between them was the first of a new generation of cranes, powered by steam and comprising a single curved metal jib, causing them to be dubbed 'swan neck'.[128] However, for all its innovatory quality this swan neck was able only to raise a load of 15 tons. Inevitably cranes of this type were capable of being increased in size, and one of 40 tons capacity was later installed on the eastern side of the Basin.[129]

Two docks were built leading from the Basin. In its original form Camber or No 7 Dock, opened in 1849, was 28ft longer than No 3, the second of Bentham's docks. This followed the use of diagonal framing which allowed a substantial increase in length, and therefore of fire power, of wooden ships.[130] Even more important in constructional terms, the entrance to Camber Dock was 23ft wider than the entrance to No 3 Dock, reflecting the additional width of vessels fitted with paddle wheels. The inverted elliptical arched entrance[131] was closed by a caisson identical to that at the entrance to the Basin.[132] At some time prior to 1858 the entrance and the dock itself were rebuilt with more steeply inclined walls, and the head was modified to take a caisson, the other side of which became the fore part of the similarly proportioned No 10 Dock, which gave on to the Harbour.[133] Together the two docks provided a second entrance to the Basin, but more importantly, until 1863 their use in combination was the only means by which vessels of an entirely new breed, such as HMS *Warrior* launched in 1860, with a length of 380ft, could be dry docked at Portsmouth.[134] That the docks of the 1843 plan should so quickly become inadequate is ample testimony to the speed of change in naval architecture which was to accelerate relentlessly during the remainder of the century.

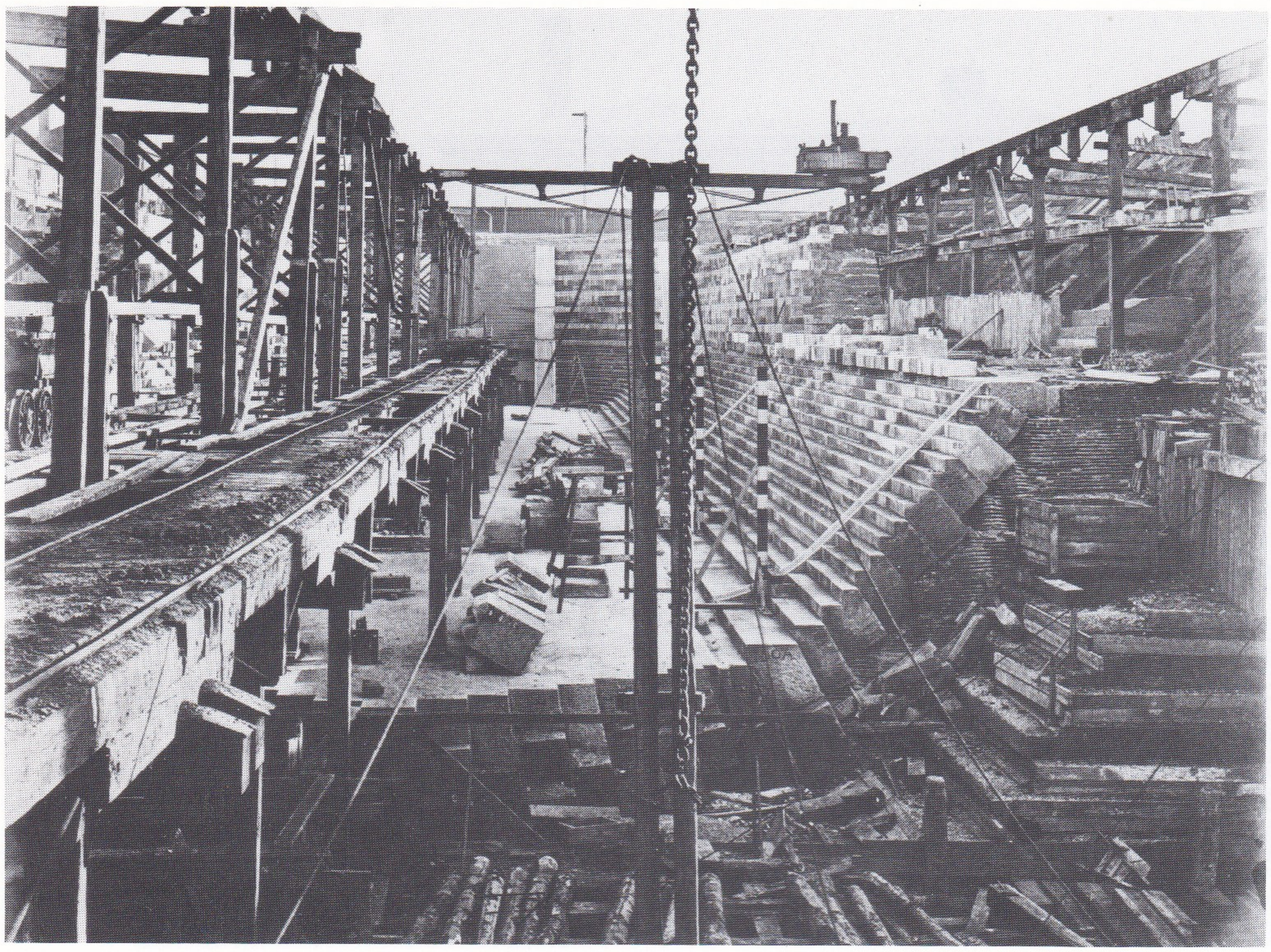
The second dock, South Inlet or No 8, was opened in 1850, Benjamin Bramble being the contractor. It was 42ft longer than No 7 Dock, even though it was completed only a year later. Moreover, the width of the entrance was a mere 65ft, some 15ft less than that of the Camber Dock, making it clear that the dock was designed for long but proportionately slim screw-driven vessels. It seems certain that this dock was the first to be erected with linear rather than curved entrance walls,[135] allowing the caisson to be placed speedily in position and the passage of paddlers to be effected more readily. This was a strategy subsequently adopted in all docks at Portsmouth. A cross section of the entrance to the dock is depicted in Figure 2. Because of the reliance on gravity flow and the distance to the pumping engine house, the bottom of the dock was 2ft above that of No 7, representing a limitation on its use.[136] Sur-

rounding the dock are metal mooring posts bearing the letters 'VR' made by H. Grissell of the Regents Canal Ironworks, London. Culverts led from both the Camber and South Inlet Docks and the Steam Basin both to the Reservoir and to the sump below the 80hp Engine House, designed by James and completed in 1849 to the west of the Steam Factory, giving considerable flexibility of operation. A dock of similar dimensions to the original No 7 was built to the north of the building slips and was opened on 23 August 1850. The advantage this dock – No 9 – possessed in discharging directly into the Harbour was eventually seen to be offset by its distance from other graving facilities, and it was filled in during the Edwardian period to provide a steel plate stacking ground for the vast No 5 Slip. The provision of space for a dock to the north of South Inlet was made in the 1843 plan, but construction was not immediately proceeded with. This was providential for it allowed the dock, North Inlet or No 11, to be built to proportions appropriate for the accommodation of the Navy's first ironclads which were being planned in the late 1850s. Completed in 1863, North Inlet Dock was 67ft longer than South Inlet,[137] and not surprisingly its volume justified the provision of a 90hp pumping engine house at its head;[138] drainage of South Inlet Dock was also effected by this facility.

Changes in the nature of the buildings no less than the docks themselves were an integral part of the arrival of the age of steam and iron, and were likewise initiated by the 1843 plan. The thrust of the extension work of the 1840s may have been in the vicinity of the Steam Basin, but the first buildings were constructed in the older part of the Dockyard. The Boat Storehouse, now No 6 Boathouse, completed in 1844,[139] was an impressive precursor of the powerful iron-framed buildings designed to meet the requirements of the new age. The two upper floors are carried on circular iron columns and girders bearing the instruction 'The load on this girder should not exceed 40 tons equally distributed over its length'. The girders are trussed with iron tie bars of the kind favoured by Robert Stephenson for some of his early bridges.[140] The subsidiary girders are slotted in position, and, indicative of the difficulty then experienced in the manufacture of interchangeable parts, they are lettered to assist erection. It is a three storey, buff-coloured brick structure with large rectangular windows, many of which were originally fitted with wall cranes, and two arched doors through which boats could be hauled from the Boat, or formerly Mast Pond; the ground floor was fitted with rails to assist the process. A drawing portraying a building very similar to that existing, signed by Captain Beatson, has survived, and it is justifiable to regard him as the architect.[141] Of the same date were the Chain Cable Store and Chain Test House by Denison and Beatson, located west of the Sail Loft, and replacing the testing ground adjacent to the Hatchelling House. The combined structure is single storey and unobtrusive, but the interior use of iron columns and slotted tie bars, together with light iron roof trusses incorporating decorative flourishes, was a new departure.[142] The floor comprises a mixture of granite sets and ballast castings bearing a variety of arrowhead designs with the letters 'Po', an indication to the commercial yards undertaking fitting out where the ballast was to be returned.

Undoubtedly the architectural gem of the 1843 plan was the Vanbrugh–like Steam or West Factory, now No 2 Ship Shop, completed in 1848 to the designs of Denison.[143] Some 600ft long and dominating the western edge of the Steam Basin, it has two storeys of deep red brick offset by Portland stone cornices and pedimented bays. The tall, metal-framed, round-headed windows served as doors in the bays at first floor level, and wall cranes and platforms were fitted at these points. The first floor is carried in a single span on brick vaulting supported by metal girders, making this the first fireproof workshop in the Dockyard.[144] The metal supports and track of the manually operated gantry crane, installed for the movement of heavy engine and boiler assemblies, survive, as does the metal spiral staircase by R. Ramsey & Sons of Berwick.[145] In the light of the importance of this building in the evolution of the Dockyard, the functions of its five sections are listed. On the ground floor from south to north were the heavy turning shop, the erecting shop, the punching and shearing shop, the boiler shop and the extension of the latter. On the upper floor were the millwrights' shop, the light turning and fitting shop, the extension of the latter, the pattern makers' shop, and the pattern store.[146] The Dockyard had indeed entered an age far removed from that of Nelson.

Not only did the 1843 plan call for the maintenance and repair of engines and boilers, but also it was intended that metallurgical work be undertaken as part of the drive to achieve a high level of self-sufficiency. An Iron and Brass Foundry, reflecting the exterior design features of the Steam Factory, and therefore almost certainly by Denison, was opened in 1848. It lost its iron founding function with the completion of the adjacent Iron Foundry in 1854, and a gantry crane track above substantial cast iron pillars by the Landport firm of J. A. Baldy, dated 1864, possibly relate to this change.[147] A new Smithery comprising a tubular metal frame hung with corrugated iron sheeting was completed in 1852. The original intention was to build a brick structure in keeping with the Steam Factory to designs proposed by James, but as a measure of economy they were set aside,[148] and materials from the Great Ex-

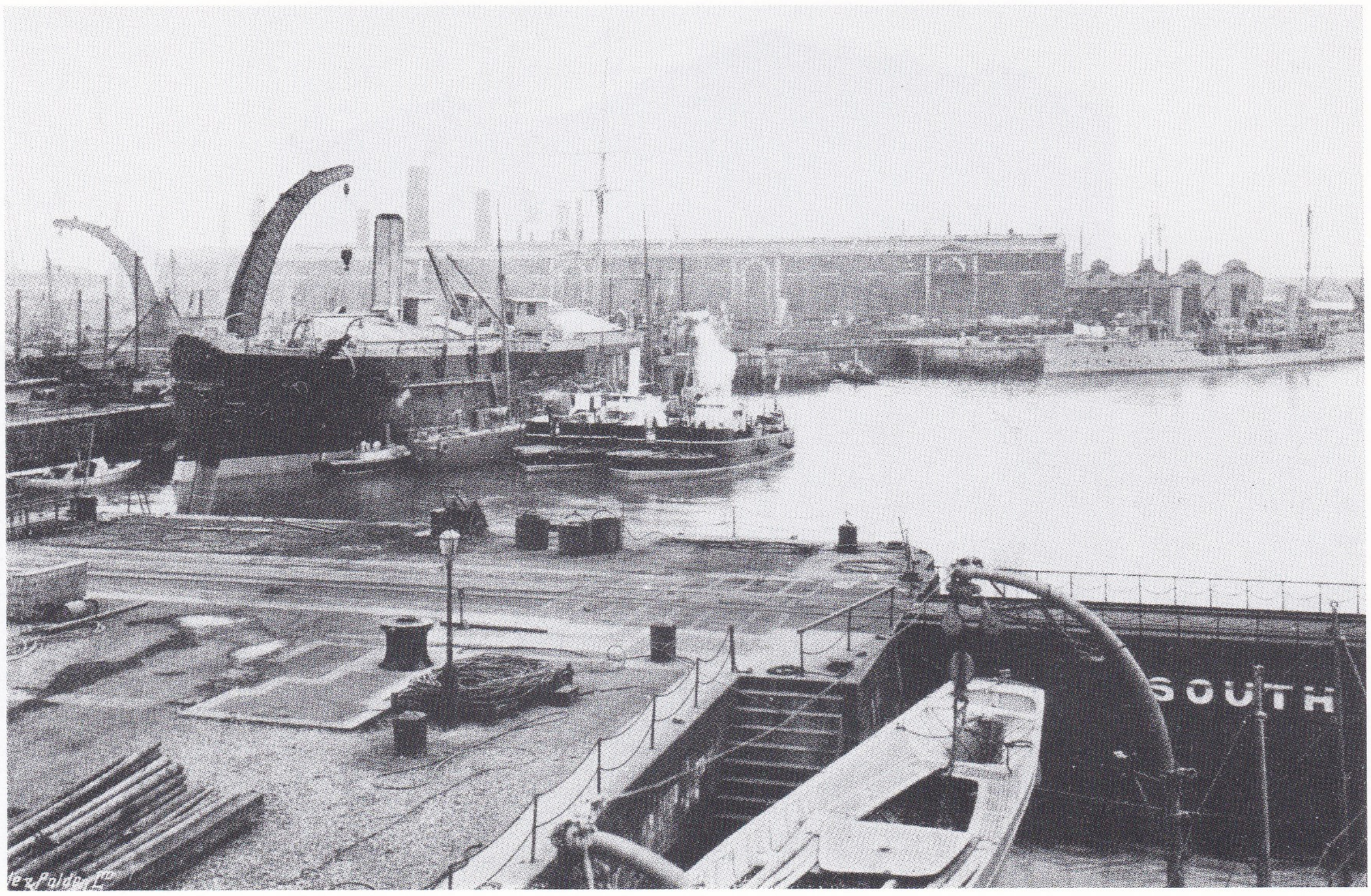


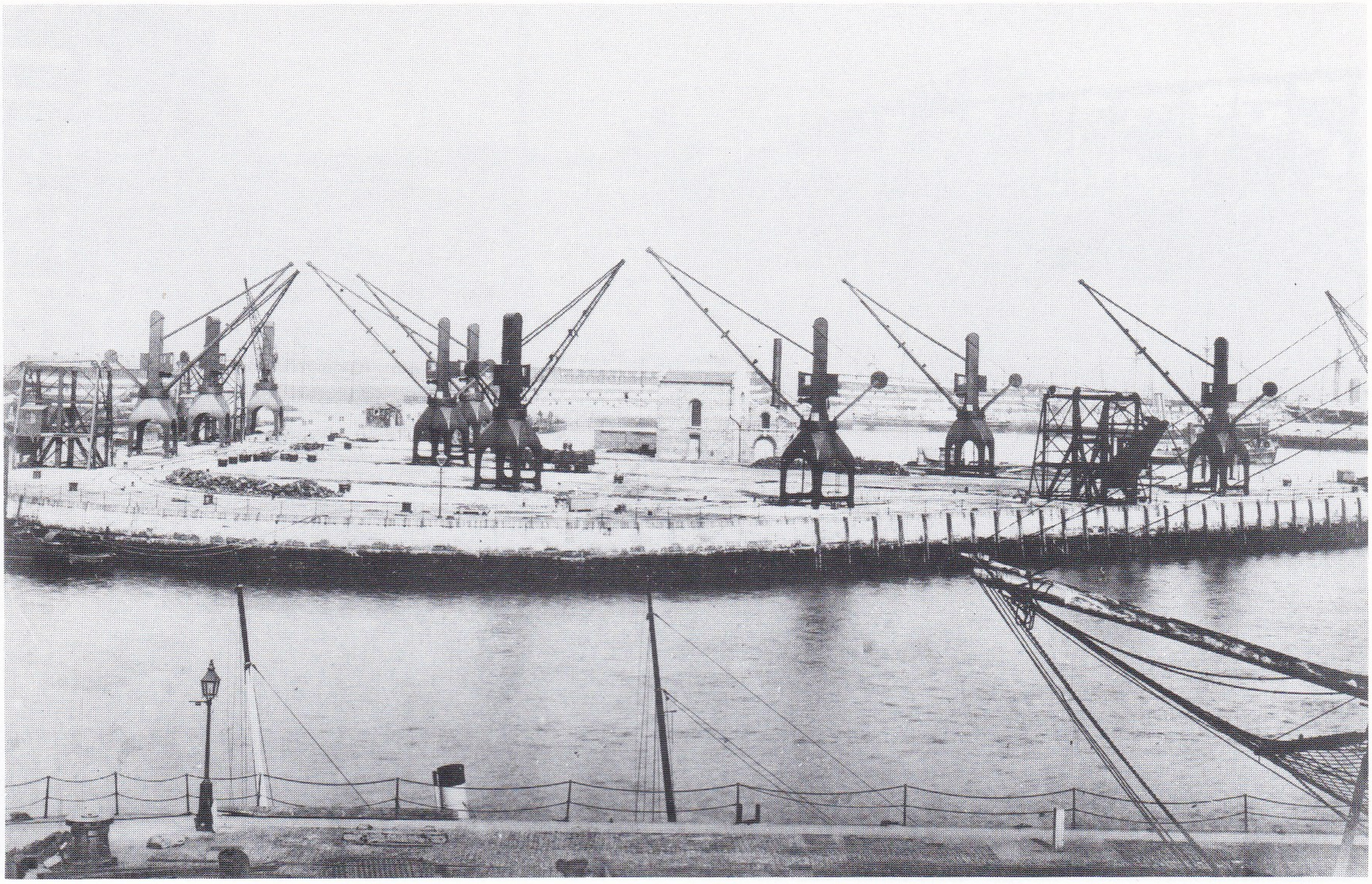
No 12 Dock under construction, photographed on 15th April 1870.
Portsmouth Central Library.

Middle or No 10 Store.
Photo Brian Sprunt.

The Boat Store or No 6 Boathouse.
Photo Brian Sprunt.

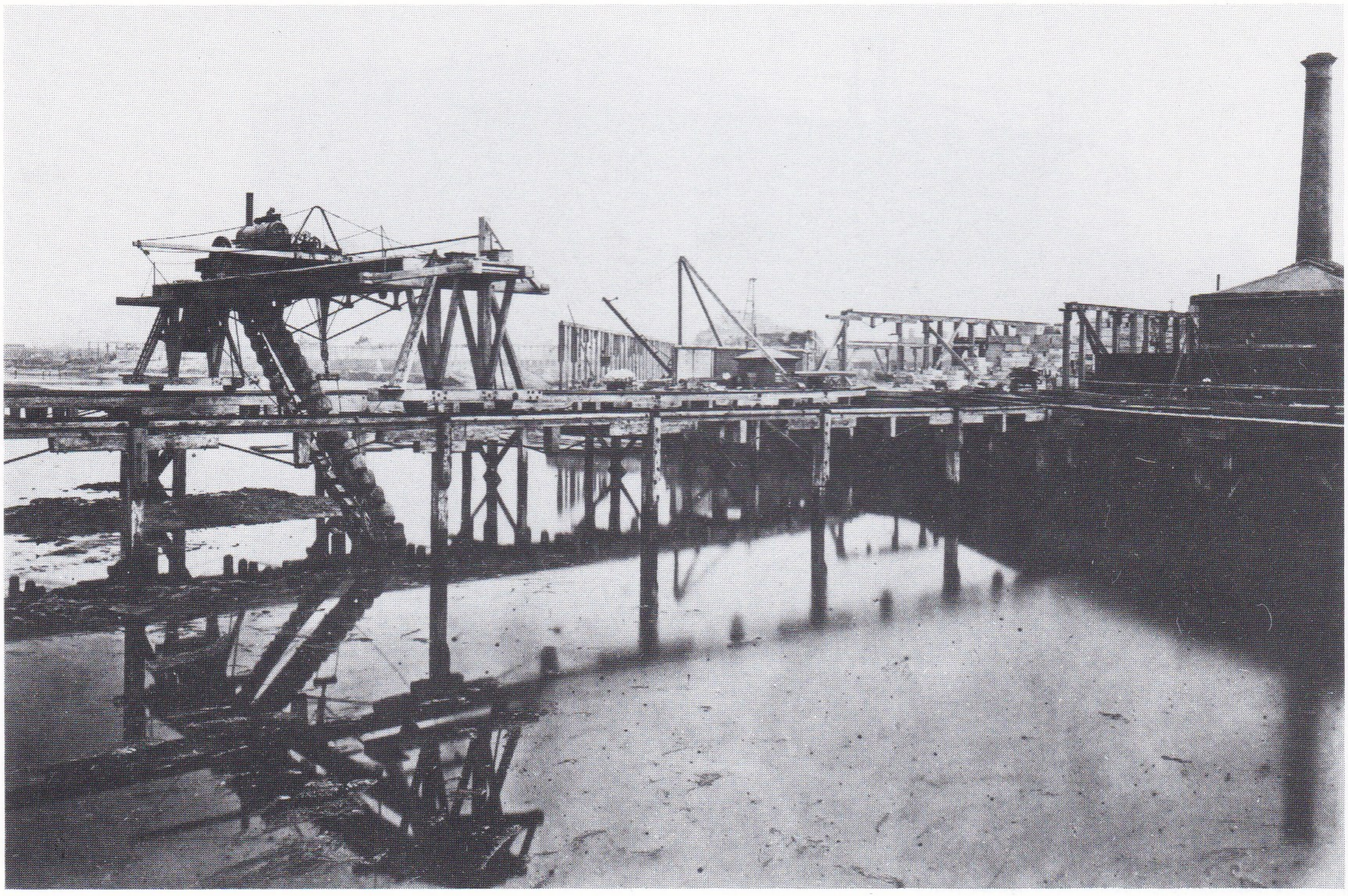
The Tidal Basin in the early years of the century. In the middle ground are 'swan-neck' cranes; in the background lie the Steam Factory, the chimneys of the Smithery and the sheer legs at the Great Basin.
Portsmouth Central Library.

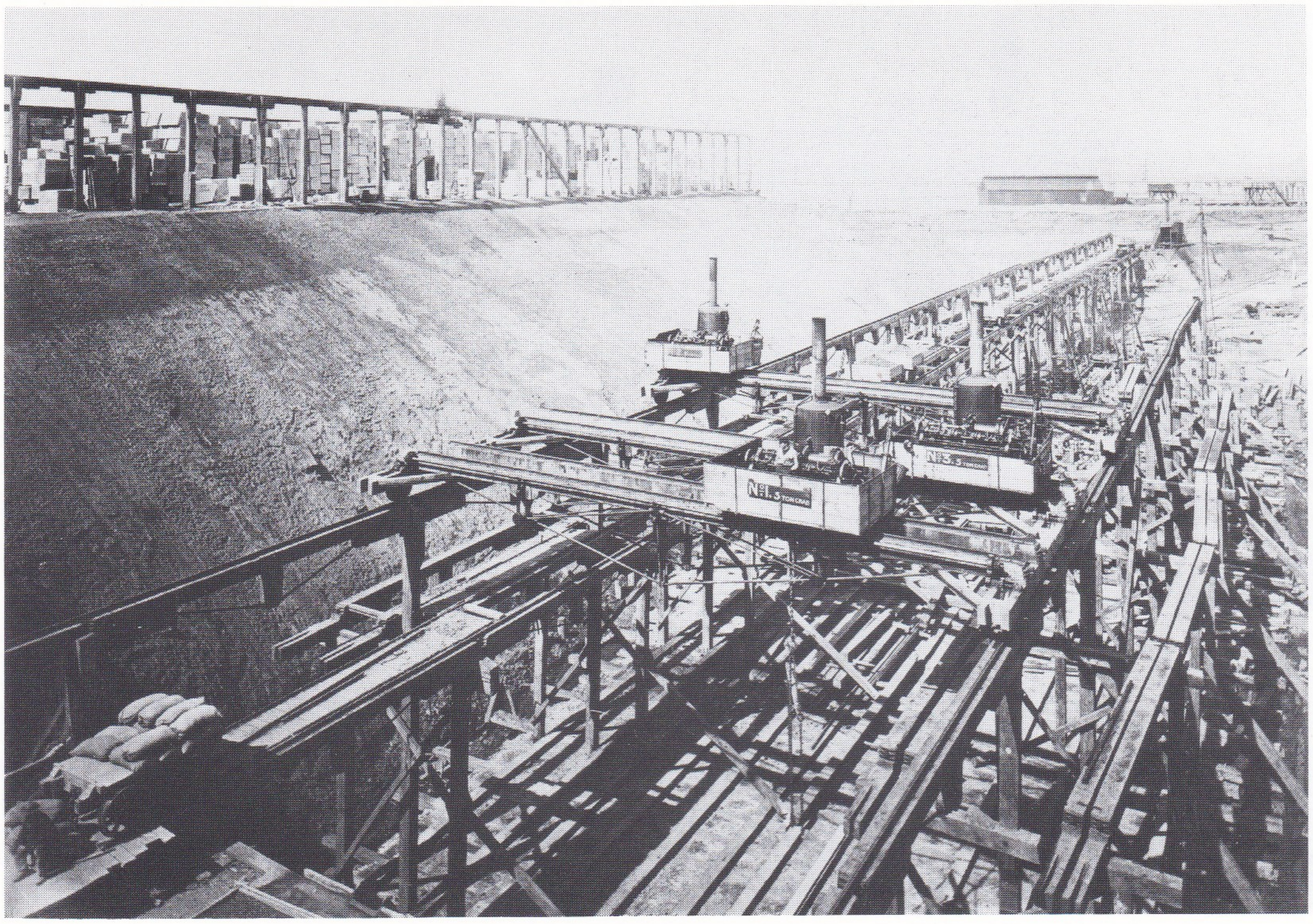




Hydraulic cranes at Coaling Point in 1910, prior to its removal to allow the construction of C and D Locks.
Portsmouth Central Library.

The 'Goliah' steam dredger used in the construction of the Great Extension, photographed on 8th June 1868.
Portsmouth Central Library.





Steam gantry cranes known as crabs employed to manoeuvre heavy masonry in the construction of No 13 Dock, photographed on 15th April 1870.
Portsmouth Central Library.

The supporting structure of the Water Tank, later used as the Dockyard Fire Station.
Photo Brian Sprunt.

hibition employed instead.[149] At each corner stand the square bases of now truncated chimneys bearing a simple stone shield and date, illustrative of the wind of parsimony blowing at the time. With its many hearths, wall and swan neck cranes and enormous steam hammer for fashioning anchors, the Smithery was redolent more of the Black Country than of a south coast town. The Iron Foundry, which was not finished until 1854, also bears a strong visual resemblance to the Steam Factory, and even if not by Denison, it owes much to his inspiration. Fortunately the 1873 extension meshes sympathetically with the whole. Because of the provision of railway access, the four main entrances are wide and have been given powerful arches of Portland stone strengthened by iron transoms to carry the weight of the masonry above. The risk of fire was clearly uppermost in the architect's mind, for not only does the upper floor incorporate a water sprinkler system fed by a tank on the roof, but also the metal staircase is enclosed in cast iron panels, bearing the letters 'Po Yd', as a fire containment strategy. Similarly inscribed cast iron doors on the first floor have the same purpose.

Although it was Admiralty policy to put out most construction work to commercial yards, building capacity at Portsmouth seems to have been regarded as inadequate, and in 1838 a fourth slip was built by Benjamin Bramble.[150] A fifth appears on a plan on 1849.[151] Bentham's proposal in 1811 that the head and sides be enclosed and fitted with windows[152] appears to have been heeded, for a painting of 1842 clearly illustrates these features on North, Middle and South Slips.[153] However, the combination of strength and lightness of metal as a constructional material gave rise to its imaginative use in new roofs for North Slip (No 3) and No 4 Slip in 1845–6. Utilising the new galvanised corrugated iron, frequently interspersed with glazed skylights, each roof had a span of 84ft 6in, greatly facilitating construction work on ships, and predating the great railway trainsheds. Once again Denison was involved, and at his instigation the roof trusses were strengthened following experiments he conducted to predict the force of the strongest gales likely to be experienced. The contractors were Baker & Son of Lambeth.[154] Nos 4 and 5 Slips were longer than their predecessors and the landward end of No 5 was built with a raised roof to assist work on ships' bows.[155] It is likely that the roof was of similar design to its two adjacent fellows. The small size of these slips rendered them of scant relevance to the ironclad Navy and this was seen in the use to which they had been put by 1900. South Slip (No 1) had become the Boat Slip for the Dockyard Steam Reserve, North Slip was a 'hauling up slip for torpedo destroyers', that is, it had lost its building use, and No 4 had been filled in and had become a Shipbuilding Shop.[156] Shortly afterwards No 5 Slip was greatly extended to a length of 666ft to allow the construction of Dreadnoughts in the final headlong rush into war. Since metal ships, and indeed shipwrights, were not thought to require protection from the weather, no roof was provided.[157]

Given the unevenness of the roadways and the weight and quantity of materials regularly moved within the Georgian Dockyard, quite apart from the presence of such clear-sighted men as Bentham and Goodrich, it may be assumed that some form of tramway must have existed. Certainly such was in operation in 1828 when convicts from the hulks were ordered to take over the haulage of trams from horses.[158] A granite tramway is known to have existed in 1835 for the haulage of masts from the Mast Store near the Mast Pond to Sheer Jetty, north of the entrance to the Great Basin.[159] Here the tramway tracks merged with the broad capstones of the Basin rim, assisting movement on this section of its perimeter. This system was extended by James so that it ran as far as the Mast House near the Main Gate.[160] It comprised parallel slabs of flat granite some 2ft 3in wide, separated by Guernsey pitchers 2ft 10½in across set in a concrete bed. A standard gauge railway, probably worked by horses and capstans, was laid down round the Steam Basin as part of the project, and the granite tramway was extended to meet it at a turntable south of the caisson to the Camber Dock, the wheels of the tramway trucks being redesigned to allow them to work on both systems. James employed bridge rails, such as those favoured by Brunel,[161] with an angle iron on the inner side to protect the channel for the wheel flanges, lying on longitudinal sleepers resting on transverse baulks of fir set in concrete, an outstandingly sturdy arrangement for slowly moving trains. A branch of the railway, which was single track throughout, and thus hardly conducive to smooth operation, ran east to the timber stacking ground and to the casemates of Frederick's Battery, a seventeenth century defence work which was used as a coal store. The Dockyard railway was linked in 1849[162] to the main line system by means of a single track line from Portsmouth Town station which crossed Commercial Road on the level and breached the Portsea fortifications at their northern extremity. Steam locomotives would thus have made an appearance in the Dockyard for the first time. They were not able to pass beyond the reception yard, however, because of the numerous turntables installed as the simplest means of negotiating right angle bends in the roadways. Indeed, it was not until 1869 that a locomotive was acquired for duties within the Dockyard, horses being employed before, and for some time after this date. It is possible that from the late 1860s the movement of trucks was also achieved by hydraulic capstan. The granite tramway was made redundant by the

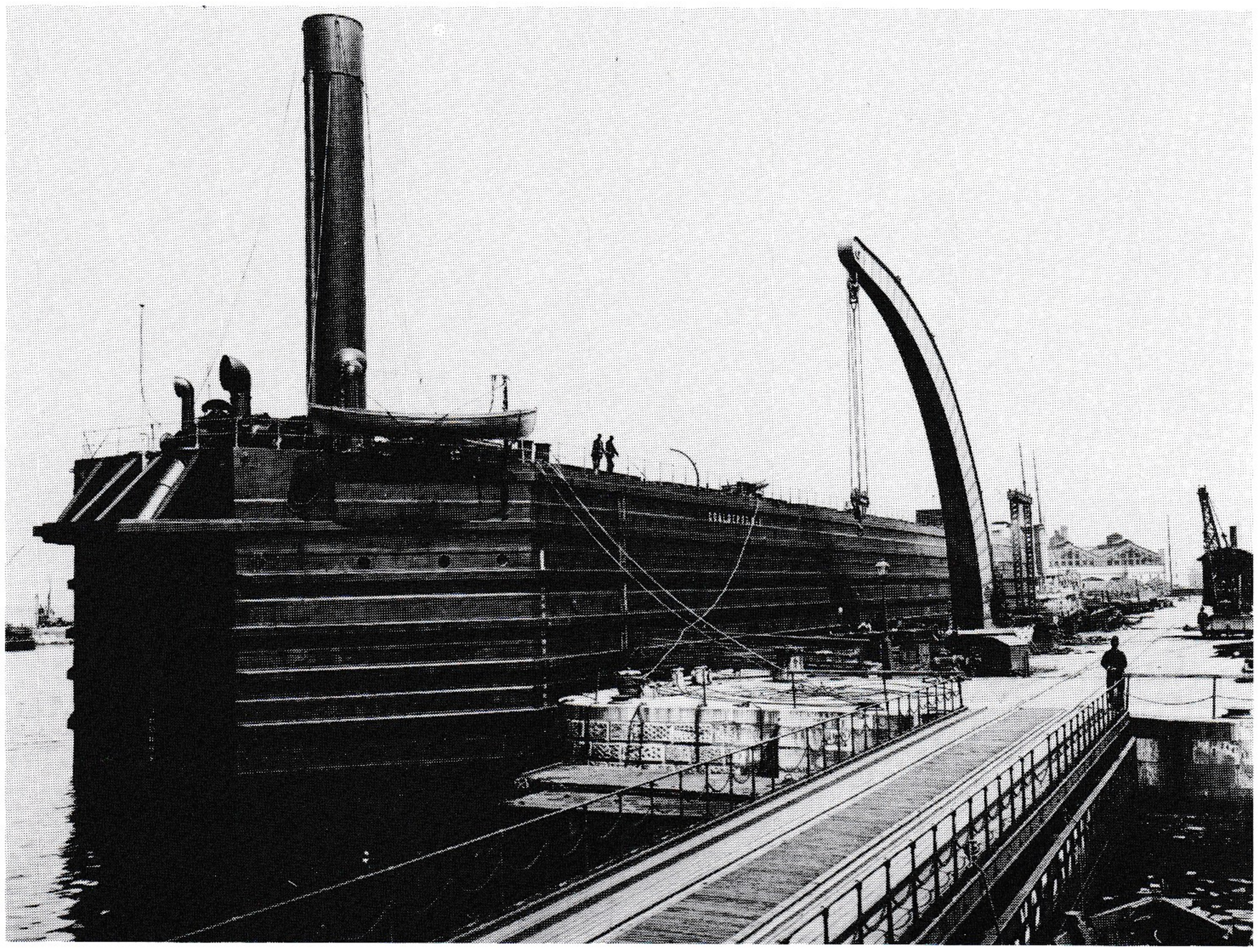
The 12,000 ton coal depot ship which arrived in the Dockyard on 27th June 1904. Reputed to be the largest vessel of its kind in the world at the time, it was subsequently fitted with cranes of its own. In the foreground is a 'swan-neck' crane and in the background is Frederick's Battery.
Portsmouth Central Library.

subsequent invasion of the Georgian yard by the railway, but large scale maps of the 1870s indicate that prior to its demise it had generated branch lines somewhat smaller in width running to Nos 1, 2 and 3 Docks.[163] One short section near No 1 Dock survives; the granite slabs are 11in wide separated by a 3ft 2in section of rough sets. Trucks used on the main tramway could have travelled on this line, but without much room for error, suggesting that those employed were of a narrower gauge than those working on the main system. Developments in dock and building construction may have overshadowed change in the more mundane field of transport, but arguably the Dockyard was host to the principal stages in the evolution of rail transport; from granite slabs to rails and from manpower through horsepower and possibly capstans to locomotives, underscoring the significance of the establishment in industrial history. The location of the early Victorian docks and building appears in Figure 1.

The Threat of War with France; The Great Extension 1867–1881

The perceived threat posed by the French, which gave rise to the construction of a ring of land and sea forts round Portsmouth Harbour, had a far-reaching impact upon the Dockyard itself. It had become clear that the Steam Basin and associated docks were quite inadequate to deal with more than a few of the new metal-hulled leviathans. By the time North Inlet Dock had been commissioned, four iron armourclads,[164] as they were known to distinguish them from wood armourclads, of such a length had been launched that they could be accommodated only in the aforementioned dock and Nos 7 and 10 used in tandem. Further, not only were similar vessels in the course of construction, but also there seemed no reason for thinking that even bigger ships would not be feasible. Additionally it had become apparent that iron vessels were more prone than wooden ships to develop encrustations of barnacles and seaweed on their hulls, necessitating more frequent docking for cleaning.[165] In 1864 the Admiralty therefore obtained parliamentary sanction for a very substantial extension programme which almost trebled the area of the Dockyard.[166] No less than half the new ground, some 95 acres, was to be reclaimed from the Harbour, itself a formidable challenge to civil engineering. The overall scheme was drawn up by Colonel Sir Andrew Clarke, RE, and superintendence was undertaken by H. Wood, J. Macdonnell and Charles Colson, civil engineers on the Admiralty staff.[167] The contractors were Leather Smith & Co.[168] It is to the planners' great credit that although neither the size nor the sheer number of vessels later to be involved in the rearmament programme could have been envisaged, no further extensions should prove necessary, even if there were later modifications within the boundary wall.

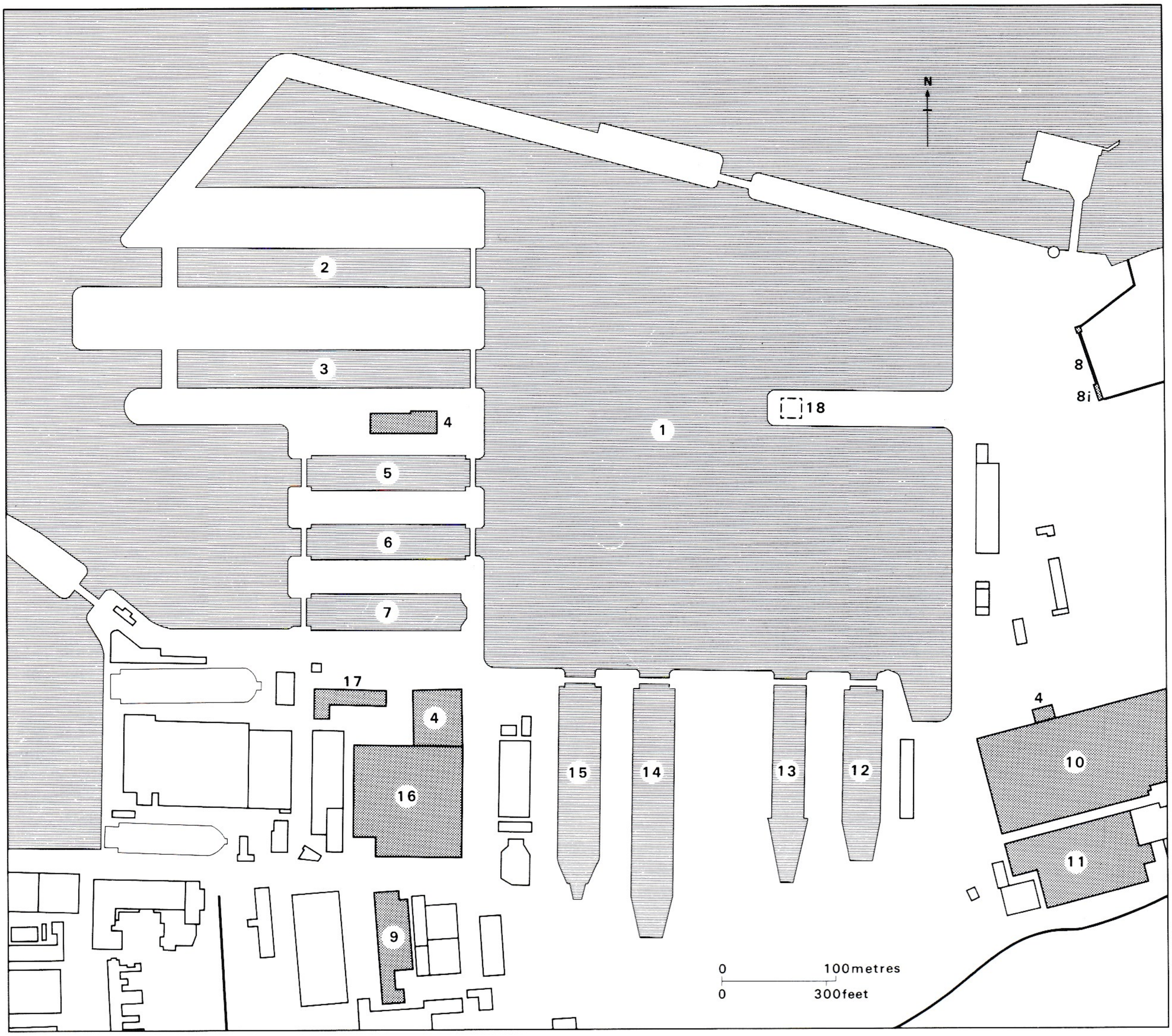
The scheme called for the construction of a tidal basin, two locks leading to a vast repairing basin, from which vessels were to move into a rigging basin and transfer to a fitting-out basin before leaving via a tidal basin. In addition three docks were to be built, with provision for two more should they be required. Work began in 1867.[169] The central feature was the 22 acre Repairing Basin, access to which was achieved through the 9 acre Tidal Basin and North and South, now B and A Locks, both of which were 58ft longer than North Inlet Dock. To enable vessels to enter the locks from the Tidal Basin at any state of the tide, the western lock entrances were constructed to provide 41ft 6in of water at high water springs, their entrances giving into the Repairing Basin drawing only 33ft since here the height of water could be controlled by pumping. The caissons between the locks and the Repairing Basin were conventional floating structures, but those at the opposite end of the locks and the four closing the 15 acre Rigging Basin and the similarly sized Fitting-Out Basin operated on the sliding principle, generating both labour economies and speed. They were carried on wheels and were withdrawn beneath metal plates forming the surface of the quay, by a pair of horizontal engines driven by compressed air.[170] The Repairing Basin, locks and Tidal Basin were completed in 1876, and the two basins in 1881.[171] Consequential upon the availability of some 91,000ft of wall for wharfage,[172] there was a concomitant increase in the number of cranes, but although lifting capacity was raised to 20 tons and compressed air supplied from a ring main encircling the Repairing Basin introduced as power, the swan neck, albeit enlarged, with its fixed radius, persisted as the standard equipment.[173] Equally, sheer legs for the raising of heavy loads to substantial heights remained the order of the day. Those installed on the eastern side of the Repairing Basin in 1874 by James Taylor of Birkenhead, with a capacity of 80 tons, the back leg being operated by a steam-powered screw giving a 40ft overhang and a 120ft lift,[174] performed well into the era of much more sophisticated cranage. Not until 1881 did cranes of a new type make their appearance. Hitherto the cranes employed for coaling had been manual, but the need for mechanical assistance with this dirty and arduous task was clear, and ten 30 cwt hydraulic cranes were introduced at Coaling Point, west of the Fitting-Out Basin. Their four curved legs and body resembling some bizarre form of marine life, these cranes provided the operator with a cab, but the provision of a counterbalance represented a new departure which was to presage the advent of very much larger and more flexible machines.[175]



Three dry docks of broadly similar dimensions were constructed during the Great Extension. The key issue was length since it was this rather than width of ship that was dramatically increasing. Measured from the broad altar at the head to the inside of the entrance, all three docks had a length of between 410ft and 417ft,[176] ample for contemporary, if not later, warships. Deep Dock, which came to be designated No 9 Dock, after the filling in of the original dock of this notation, was built in parallel with North and South Locks and opened into the Tidal Basin, its entrance being closed with a sliding caisson. In order that ships could be dry docked irrespective of the tide, the depth of water above the invert was 41ft 6in at high water springs, unequivocal justification for the epithet 'Deep'. By comparison Nos 12 and 13 Docks on the south side of the Repairing Basin offered a depth of 33ft 4in and 33ft 10in respectively. Unlike Deep Dock, these two docks had conventional caissons. The rapid evolution of gunnery technology requiring an ever increasing size of ship caused both Nos 12 and 13 Docks to be lengthened respectively in 1903 and 1905,[177] in the latter instance by more than 100ft. The pumping engine house for the new works was appropriately powerful and originally contained two inverted compound steam engines with a total capacity of 1,000hp, driving plunger pumps capable of removing 18,000 tons of water per hour.[178] The building also housed the air compressors for the caissons and some of the capstans and cranes, and following Bentham's earlier example, salt water tanks linked to a salt water firefighting main were built into the roof. Clearly an engine house with its adjacent boiler house and chimney, the building bears some similarity to Denison's work, but is distinguished by a series of high level port-hole windows. Although the docks became operational on 27 April 1876, the engine house was not completed until 1878 and a temporary facility was erected until it could be brought into service. As befits an ephemeral structure, it was pedestrian, but it says much for the Victorian sense of priorities that the boiler chimney was given a decorative cornice even though its life span could barely have exceeded three years.[179]

The excavation and constructional work of the Great Extension raised formidable problems for the engineers, not only because of the scale of the project, but also since the Harbour mud was so soft that all the work had to be carried out from stages mounted on piles. Thus the nine miles of road and the railway tracks, which were capable of accommodating locomotives weighing 18 tons running at speeds up to 15mph, were effectively viaducts. There were additionally four miles of track on which self-propelling steam gantry cranes were mounted,[180] principally for the purpose of receiving granite blocks from railway trucks and lowering them into position. Even more massive were Goliah travelling steam dredgers operating endless chains of buckets discharging mud into railway wagons,[181] which were then hauled by locomotives, of which there were thirteen on the site,[182] across Fountain Lake on a viaduct to jettison their load at what gradually emerged as Whale Island.[183] Pile driving was facilitated by the use of an improved steam driven machine[184] developed by three resident civil engineers, C. H. Meyer, E. P. Smith and Ernest Latham,[185] but an even more important saving stemmed from the Victorian belief that convicts should earn their crust. Housed in a prison built in 1850 immediately outside the Dockyard wall, some seven to eight hundred convicts were employed as general labourers and in the large brickworks which at one point made 20 million bricks a year from clay dredged from the excavations. Even geology conspired to assist the Admiralty, and the taxpayer.

The first of the production facilities associated with this wave of expansion was the Engine Smithery, built on the site of timber sheds and saw pits to the west of the Steam



1 No.3 Basin
2 D Lock
3 C Lock
4 Engine Houses
5 North Lock
6 South Lock
7 No.9 Dock
8 Frederick's Battery
8i Gas Meter House
9 Power Station
10 Factory
11 Torpedo Shop
12 No.12 Dock
13 No.13 Dock
14 No.14 Dock
15 No.15 Dock
16 Gun Mounting Shop
17 Painters' Shop
18 250 ton Crane

Factory, *c.*1865. Although it was demolished to make way for No 5 Slip in its later form, it is mentioned here since it represented a new direction in building style. It was iron-framed and clad with corrugated iron pierced by large round-headed windows, but unusually the roof, also of corrugated iron, was curved and fourteen circular metal chimneys and a series of ventilators protruded through it.[186] It represented a highly functional and unattractive addition to the Dockyard's stock of buildings, and was fortunately not replicated. Very different was the Armour Plate Workshop, later No 1 Ship Shop, of 1867. Its architectural style owed much to the period of expansion two decades earlier, and a feature was made of the two entrances by providing them with Italianate towers, pierced by slim windows and surmounted by a finial.[187] The shop had its west wall knocked out when the adjacent open-sided sheds[188] were removed and the space incorporated into an enlarged workshop in the 1880s, four rows of twin octagonal columns by the Cargo Fleet Iron Company being inserted to carry the new roof. The weight of materials to be lifted justified the use of hydraulic equipment, the power for which was generated in an engine house of matching style proximate to the southern entrance. Dating from the 1870s are the Camber Boathouses into which small boats were craned for repair. Such is the frequency of the entrances on all four sides that the narrow intervening walling is buttressed to take the weight of the roof, creating a building of curious aspect.

The majority of the industrial buildings resulting from the Great Extension date from the 1880s. Advances in gunnery called for specialised buildings and in 1886 the Gun Mounting Shop was opened. The structure relies on

Figure 3 The Mid- and late Victorian Docks and Buildings in Portsmouth Dockyard.

round-headed windows and recessed brick courses for effect, but the principal innovation was the compartmentalisation of the six interior bays by strong walls not carried up to the roof; these were used as the base for travelling cranes needed to lift the very heavy guns of the day.[189] A further bay was added to the western end in 1913 and electricity provided the power for the travelling crane. The Torpedo Store of 1886 was a similar response to technical change in armament, although the size of the building may have been influenced by the experimental work that came to be undertaken on Horsea Island.[190] Its most notable feature is a truly outstanding low relief in one of the three south facing gables. Even the single storey Gun Mounting Store, built in 1889 on the eastern rim of the Repairing Basin, was given fenestration redolent of Denison, together with arches with brick and Portland stone voussoirs, creating a pleasing chequerboard effect. The Painters' Shop, again of one storey, its gables edged with Portland stone and its windows reminiscent of the Steam Factory in miniature, is further evidence of the rich styling the Admiralty saw fit to bestow on their buildings.

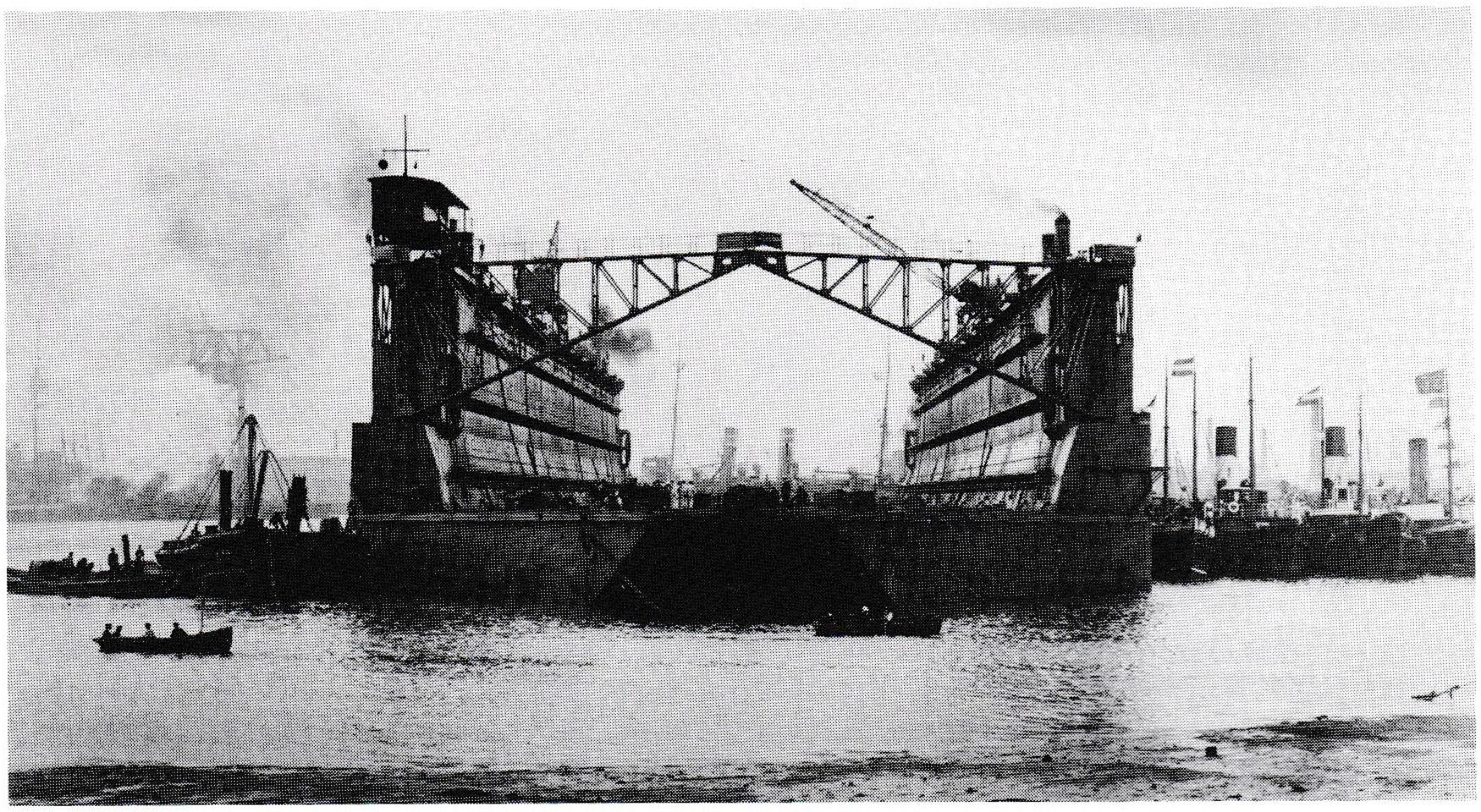
Because the materials from which iron vessels were made were less susceptible to the vagaries of the weather than those used in wooden shipbuilding, the Great Extension generated little fresh storehouse capacity. One such facility was No 12 Store, to the west of Middle Store, thus cutting off the latter from direct access to the Camber. The general principle laid down by the Georgians of narrow width was adopted, indeed the use of iron beams to carry the upper floors, thus removing the need for interior support, caused the building to be even slimmer than its predecessors. It was much longer than the eighteenth century storehouses, and to improve access it was provided with two large entrances along its length in addition to those in the gable ends. Vertical movement was assisted by the use of hydraulic lifts, the power for which was generated in a nearby engine house with a distinctive accumulator tower. The Portland stone string course between the round-headed windows and the decorative coving and parapets all suggest a date in the 1860s.[191] This engine house activated eight cranes, nine capstans and nine lifts in the Georgian dockyard, together with the mechanism in the Chain Test House, through underground pipes which were heated by small gas jets where they entered cranes and capstans to prevent freezing in cold weather.[192]

Coinciding with the completion of the first part of the Great Extension works in 1876 was the extension of the main line from the Town to the Harbour Station, from which a single track branch was run into the Dockyard across the Common Hard on a viaduct incorporating a swing bridge to give access to the Hard. In order to make provision for twin tracks, the western edge of Watering Island was extended to create South Railway Jetty, marooning capstans on the line of the former quay edge.[193] At the same time two railway waiting rooms were erected; since that which has survived has a typical railway canopy, cast iron columns, elaborate brackets and valancing, it is possible that both were the work of the railway company. Certainly the Portsmouth Extension Railway Act required the Dockyard branch to be completed prior to the opening of the Harbour Station to traffic. Decorative they may have been, but the waiting rooms paled into insignificance compared with the resplendently painted and elegantly structured Royal Shelter erected surprisingly late in the reign of Queen Victoria, in 1893. Other than the second branch, the most fundamental change in the railway network was its extension round the Repairing Basin and the new docks and locks, and the removal of most of the turntables of the former era,[194] allowing locomotives to haul loads throughout the Dockyard. This proved to be of great convenience not only to the Admiral Superintendent and distinguished visitors, for whom a four wheel carriage known as the Special Saloon was provided, but also to the Admiralty, and arguably the nation, since the Queen agreed to launch HMS *Royal Sovereign* and HMS *Royal Arthur* in 1891 only on condition that she could alight from the royal train proximate to the docks in question.

Since some 86 acres of existing land were acquired for the Great Extension,[195] it was inevitable that some sacrifices had to be made by the residents of Portsea. There were, however, some redeeming features. The eastward march of the Dockyard, coupled with the increasing range of artillery, meant that the town fortifications could be dismantled, and it was a laudable element of Clarke's scheme that provision was made for the incorporation of the imposing Unicorn Gate, built at the north end of North Street in 1778, into the boundary wall, finished in 1870, complete with bartisans and rifle slits. Additionally, the site of the Round Tower and Frederick's Battery were required for the Armour Plate Workshop, and most commendably they were taken down and between 1870 and 1871 rebuilt in their present location in the north-east corner of the Dockyard.[196] The tower at the southern end of the Battery may have suffered the indignity of being used as a gas meter house, but at least this important seventeenth century structure survived.[197] A plan of the docks and buildings of the Great Extension appears in Figure 3.

Rearmament: The 1880s to the Declaration of War

The evocative term 'rearmament' is generally associated with the campaign of the so-called Blue Water School, headed by Admiral Sir John Fisher and Earl Cawdor, who



believed, probably correctly, that the most efficient method of defending Britain against Germany was through the existence of a supremely powerful Royal Navy, achieved by the mass production of technically sophisticated battleships and battle cruisers. HMS *Dreadnought* is the epitome of the policy. Launched at Portsmouth in 1906, she could fire eight 12in guns on a broadside compared with her predecessors' four, giving her sufficient fire power to engage the enemy outside torpedo range; moreover she was equipped with Parsons steam turbines. She simply made existing vessels obsolete. Yet the ability of technological change very quickly to render vessels of marginal use obtained just as much in the 1880s, in the form of the *Admiral* class, and in the 1890s with the advent of the *Majestic* class. It was this rapidity of obsolescence that enabled other nations to compete for naval supremacy without necessarily possessing a large navy. Germany began overtly to follow this path from 1898,[198] but in a sense the principles allowing her to do so had emerged a decade and a half earlier.

In the light of the changes in warship design it was clear that while Nos 12 and 13 Docks were of sufficient dimensions to allow the construction of the mighty HMS *Centurion* and HMS *Majestic*, launched in 1892 and 1895 respectively, they would be found wanting in the immediate future, especially since the decision had been taken to build the first ship of each new class at Portsmouth. The two docks provided for in Clarke's scheme were therefore built by the contractor J. Price & Co under the supervision of Major Pilkington RE and Charles Colson, and came into service in 1896. Both docks, numbered 14 and 15, had a length of 563ft 6in, but to take account of the bilge keels or stabilisers being fitted to improve sea riding quality thereby assisting the accuracy of the guns, No 15 Dock was, at 94ft wide, some 12ft broader and squarer in section than No 14.[199] Prior to their construction, in which some 15 million bricks, many from the Copnor brickfields, were used, warships such as HMS *Powerful* and HMS *Terrible* could be docked only by virtue of the well tried strategy of employing Nos 7 and 10 Docks in tandem.[200] Yet even their great size quickly proved insufficient, with the consequence that No 15 was lengthened in 1907 and No 14 in 1914, when its measurements became a remarkable 720ft by 100ft.

Since the new docks gave into the Repairing Basin, access to the latter from the Harbour had proportionately to be modified, although by greatly extending No 5 Slip, as mentioned above, ships too large for North and South Locks could still be built in the Dockyard. The solution was to construct two further locks, to the north of those existing, sufficiently large to accommodate not only battleships of the *Dreadnought* class, but also to accommodate even larger warships such as HMS *Iron Duke*, with a length of 580ft, and HMS *Queen Elizabeth*, some 600ft long.[201] Completed in 1914 by the Glasgow contractors Morrison and Mason, C and D Locks were 850ft long and 110ft wide, dimensions which were at last found to be adequate for all subsequent naval vessels. The volume of water held in these locks[202] justified the construction of yet another pumping station since the Admiralty stipulated that the time taken for evacuation should not exceed $4\frac{1}{2}$ hours. The size and location of the new locks brought a number of changes in train. Coaling Point was subsumed within the new works, as was the larger part of the Fitting-Out Basin. The wall separating the Rigging and Fitting-Out Basins was incorporated into the eastern end of the locks, and because it interfered with access to the locks, much of the wall between the Repairing Basin and the Rigging Basin was removed. Effectively the functional areas were lost and the residue became a vast No 3 Basin. A repairing facility of a novel kind was introduced in 1912 when a floating dock was delivered from Cammell Laird at Birkenhead. It had a lifting capacity of 32,000 tons, considerably in excess of any warship then afloat, and it carried its own workshops, power plant and pumping equipment. Moreover, it could accept ships directly from the Harbour.[203] A service jetty was built for it to the north of the Round Tower, and in order that a railway link could be supplied, the northern half of Frederick's Battery, so carefully rebuilt, had to be demolished. Ironically, later the railway and, in 1984, the floating dock were themselves removed.

Concomitant with these developments was the introduction of land-based cranes embodying new principles. Hitherto dockside lifting equipment had been located at fixed points, but now travelling cranes mounted on track

The Floating Dock photographed on its arrival at Portsmouth on 22nd August 1912. The 250 tons crane may be seen under construction in the background.
Portsmouth Central Library.

were sited on the north side of No 3 Basin, one each side of D Lock and at the south-west corner of the former Repairing Basin. Further, by the use of mobile jibs, as at D Lock, or a bogie mounted on a horizontal jib, as in the case of the two tower cranes by Sir Wm. Arrol in the Repairing Basin,[204] flexibility of operation was greatly increased. By virtue of their capacity to raise loads some 120ft they also has the advantage of being able to lift to heights formerly the exclusive province of sheer legs, and of being powered by the new and highly adaptable form of power, electricity. Nevertheless, really heavy loads continued to be handled by sheer legs, and a reflection of their usefulness was the installation in 1901 of a pair of 100 tons capacity by Cowans Sheldon on the South side of the Repairing Basin; worked by steam, they had a lift of 137ft with an overhang of 53ft.[205] It was the apogee of such technology, for in 1912 the task of lifting the massive bulk of gunnery equipment was entrusted to the gargantuan 250 tons capacity, electrically-driven cantilever crane made by Sir Wm. Arrol and erected on the Promontory between the former Rigging and Repairing Basins.[206] As much as anything else this crane symbolised Portsmouth until its demolition in 1984. A floating crane with a capacity of 150 tons by Cowans Sheldon, the hull being by Denny of Dumbarton, also made its appearance in 1912,[207] but however much there is to be said for myths, it should be pointed out that the even larger 200 tons floating crane popularly supposed to have been built by German prisoners of war, did not arrive in Portsmouth from Kiel until 1923, and the crane itself was assembled by Cowans Sheldon.[208]

It was entirely appropriate, and indeed necessary in the light of the increasingly complex engineering required for the early twentieth century warship, that the largest workshop ever constructed in the Dockyard was opened shortly before the launch of HMS *Dreadnought*. With studied understatement named simply the Factory, the building was completed in 1905 in high quality red brick. It was as long as the Steam Factory, but five times as wide, and because of the use of steel in its construction, lighter and more delicate. There are two central bays, whose gable ends are particularly impressive, flanked by three smaller ones, the whole enclosing a vast area, and a record was claimed for it in this respect in the Edwardian era.[209] Such was its thirst for power that it possessed its own engine house, finished in 1903. As Balfour remarks 'it impresses by size alone; it has, and needs, little else'.[210] The growing demand for electric power for motors and illumination – crude angle poise lights were in general use in production shops by the Great War[211] – justified the installation of a power station in 1906. Although its initial capacity of 9,800kw was minuscule by present day standards, the boiler house was given a very tall chimney 200ft in height with a monolithic moulded stone and brick base. An expansion of capacity by 2,400kw proved necessary in 1912 in preparation for the new cranes round No 3 Basin.[212] No 1 Store adjacent to the South Railway Jetty dates from this period and indicates that vertical movement in storehouses had come to be regarded as undesirable. The solution was to construct a number of single storey, narrow bays, each with its own doors beneath an overall roof; here there are three parallel bays each with a decorative gable giving access to vehicular traffic, a distinct advantage over the traditional system. More prosaically but of great significance to dockyardmen was the construction of toolbox sheds. Each worker possessed his own box, which was not only heavy but also needed to be stored in an accessible fashion. Horizontal storage was space intensive and vertical stacking impractical, so inverted V-shaped metal structures with stepped sides beneath a roof were provided, requiring the shipwright to add agility to his other skills.[213]

Conclusion

While it is always dangerous to relate *prima facie* cause and apparent effect since complexity is closer to reality than simplicity, this paper has demonstrated that events in the Dockyard were powerfully influenced by government policy, allowing developments at particular times to be seen as triggered by incidents at the international level. It would nevertheless be naïve to ignore the role of technology, which has always had an intimate relationship with political endeavour, none more so than in the Victorian and Edwardian era. Moreover, the minutiae of change must ultimately be determined by men of vision nominally working for their masters. Without Dummer, Bentham, Brunel, Goodrich, Denison, James, Beatson, Clarke and Colson, to name but the principal actors, the stage of Portsmouth Royal Dockyard would have taken on a very different aspect, and arguably the play less subject to justifiable acclaim.

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1 Earlier dock building had consisted of a stone quay in what later came to be King's Mill Pond, built in 1212 and abandoned in 1228; a wooden-sided, double-gated dry dock, the first in the Royal Dockyards, built in 1496 (Chatham's dry dock was not opened until 1581) in the vicinity of No 2 Dock, and filled in in 1623; a dry dock completed in 1658 and extended to create a double dock in 1662; and a further dry dock built in 1686. For corroborative evidence of this sequence, see R. S. Horne, *H.M. Dockyard at Portsmouth A Chronology*, mimeo, 1965, 24. The location of the 1658, 1662 and 1686 docks may be seen in D. Hodson, *Maps of Portsmouth Before 1801*, Portsmouth City Council, 1978, map 13. Details of the 1658 dock are given by A. J. Marsh, 'The Navy and Portsmouth under the Commonwealth' in John Webb, Nigel Yates and Sarah Peacock (Eds), *Hampshire Studies*, P(ortsmouth) C(ity) R(ecords) O(ffice), 1981, 120–1. A general history, lacking sources, may be found in Vice-Admiral Sir Henry Kitson, 'The Early History of Portsmouth Dockyard 1496–1800', *The Mariner's Mirror*, 33, 1947, 256–64.

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